Chapter 16
Closure Terms

Four types of water supply are represented in CalSim 3.0: rim inflows from mountain and foothill watersheds, surface runoff from the valley floor, deep percolation to groundwater from precipitation and irrigation within the valley floor, and subsurface boundary inflows to the Central Valley groundwater aquifer. These water supplies are exogenous to the model, are predetermined, and are represented by monthly time series input data. Rim inflows are discussed in Chapter 5, surface runoff is discussed in Chapter 10, and deep percolation and subsurface boundary inflows are discussed in Chapter 15. This chapter introduces the concept of closure terms as stream inflow adjustments. The closure terms adjust surface water supplies (rim inflows and surface runoff) using historical streamflow data as a reference or control. This chapter discusses the derivation of the closure terms and summarizes their values in a series of charts and tables.

Background

The CalSim II hydrology is based on historical streamflow data. CalSim II uses accretion and depletion time series to resolve differences between calculated streamflows from a mass balance and historical stream gauge records. These accretions and depletions assure that the total availability of water from the Sacramento Valley is consistent with the historical record. The accretions and depletions include all sources and sinks of water not explicitly represented in CalSim II. Thus, CalSim II accretions include inflows from tributaries to the Sacramento River not represented in the model and inflows from surface runoff on the valley floor.

For CalSim II, it is assumed that sources (inflows) and sinks (consumptive use) of water not explicitly represented in the model that existed at a historical level will also exist, mostly unchanged, at an existing or future level of development. Therefore, accretions and depletions are included in CalSim II when simulating existing or projected levels of development, but are adjusted to account for land-use change and the resulting changes in depletion of precipitation.[1]

Two major changes have been introduced in CalSim 3.0. First, CalSim 3.0 explicitly represents *all* inflows from the rim watersheds that surround the valley floor. Second, CalSim 3.0 uses an integrated hydrology model for the valley floor watersheds that accounts for all components of the hydrologic cycle (i.e., surface runoff, infiltration, root-zone storage, evapotranspiration (ET), and deep percolation). These changes were motivated, in part, by the desire to be more explicit

[1] Depletion of precipitation is calculated using DWR's Consumptive Use (CU) computer program. The land-use change runoff adjustment is calculated as the projected replaced native vegetation consumptive use, minus the projected consumptive use of precipitation by crops, minus the historical replaced native vegetation consumptive use, plus the historical consumptive use of precipitation by crops.

about the inflow hydrology and to quantify model accuracy. Removing all rim inflows and surface runoff from the CalSim II accretions and depletions results in a time series of remaining discrepancies (between gauge data and calculated flows from a flow balance). These discrepancies may be caused by errors in boundary rim inflows and precipitation data; use of an over-simplified uncalibrated rainfall-runoff model; poor estimates of historical stream-aquifer interaction; and stream gauge error. It is hoped that explicitly identifying the magnitude of these discrepancies will direct future efforts to improve the Sacramento Valley hydrology. The name “closure term” was chosen for these remaining discrepancies because it more accurately reflects their derivation.

Historical Flow Balance

CalSim 3.0 uses historically observed hydrology to study how existing or planned facilities may be operated to meet competing demands for water. Historical surface water supplies consisted of inflows from the rim watersheds, supplemented by runoff from the valley floor and groundwater accretions to the stream system. Historical streamflows were depleted through diversions and augmented by return flows. The net effects of all these processes were integrated into the observed flows on the valley floor.

As part of CalSim 3.0 hydrology development, a set of monthly historical water budgets were developed. Water budgets can be calculated along river reaches where reliable gauge data exist for the entire period of simulation at both upstream and downstream ends of the reach. These key gauge locations are referred to as “control” points as flows at these locations are used to correct the CalSim 3.0 surface water hydrology.

Figure 16-1 illustrates components the flow balance. Historical streamflows (Q_{in}) and (Q_{out}) represent flows at upstream and downstream gauge locations. Water users divert from the stream system and a fraction of the diverted water (and a fraction of groundwater pumping) returns to the stream system downstream.[2]

Figure 16-2 diagrammatically show the location of control gauges in the Sacramento Valley. Figure 16-3 shows the upstream and incremental drainage area between control points in the Sacramento Valley. The drainage area between Shasta Dam and the Sacramento River above Bend Bridge is considerable and includes inflows from many rim watersheds. Similarly, the drainage between the Sacramento River above Bend Bridge and the Sacramento River at Butte City is large and includes several major rim watersheds. However, downstream from the Butte City gauge, the Sacramento River is confined by levees. There are no contributing flows from rim watersheds for control points on the Sacramento River below Wilkins Slough, at Verona, and at Freeport.

[2] A notable difference between the CalSim 3.0 formulation for closure terms and the formulation used for the CalSim II accretions and depletions in the Sacramento Valley is that in CalSim 3.0, depletions of applied water are implicitly represented by the difference in surface water diversions and return flows. In CalSim II, these depletions are calculated explicitly based on historical land use and monthly soil moisture accounting.

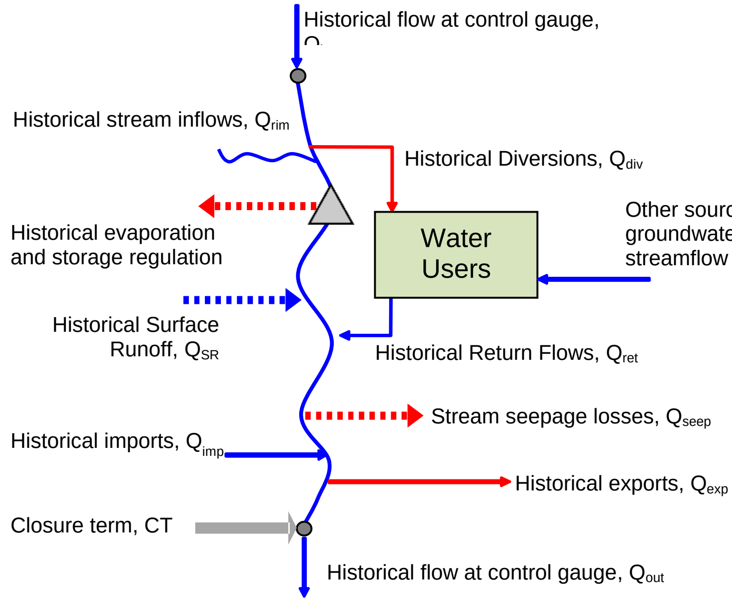

Figure 16-1. Historical Water Balance

$$\text{Closure Term} = Q_{out} + Q_{exp} + Q_{div} + Q_{seep} + E + \Delta S - Q_{in} - Q_{rim} - Q_{ret} - Q_{imp} - Q_{SR} \qquad \text{Eqn. 16-1}$$

where:

Q_{in}	=	Historical flow at upstream control gauge
Q_{out}	=	Historical flow at downstream control gauge
Q_{imp}	=	Historical canal imports
Q_{exp}	=	Historical canal exports
Q_{div}	=	Historical stream diversions
Q_{ret}	=	Historical irrigation return flows
Q_{seep}	=	Historical stream seepage losses to groundwater
Q_{SR}	=	Historical surface runoff within valley floor
Q_{rim}	=	Historical inflows from rim watersheds
E	=	Historical reservoir evaporation
ΔS	=	Historical increase in reservoir storage

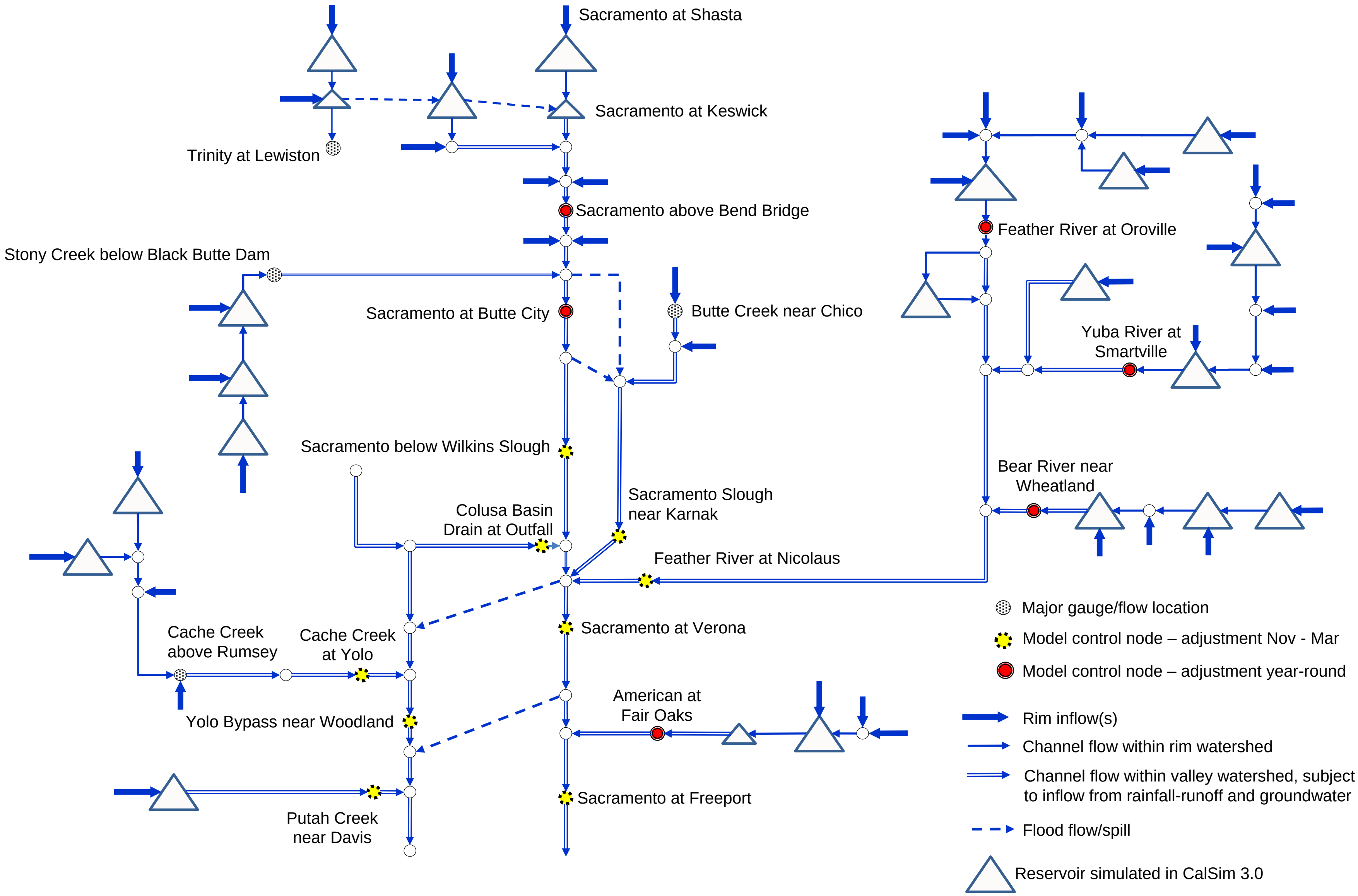

Figure 16-2. Location of Control Points in the Sacramento Valley

Figure 16-3. Control Gauges and Contributing Drainage Areas in Sacramento River Hydrologic Region

Bias and Error Correction

CalSim 3.0 closure terms correct hydrology components that are exogenous to the model (i.e., rim inflows and surface runoff on the valley floor). They do not correct for errors in components that are dynamically simulated in CalSim 3.0 (i.e., surface water diversions, return flows, and groundwater inflow to the stream system). These latter components may be adjusted and refined through water use parameters included in the Water Resources Simulation Language (WRESL) code and lookup tables, or through further calibration of the CalSim 3.0 groundwater module.

Rim Inflow Corrections

Historical inflows from the rim watersheds typically are from direct gauge measurement. Where necessary, historical gauge data are extended to cover the entire period of simulation through correlation of annual observed flows with annual flows from adjacent gauged watersheds. Derived annual flows are disaggregated to a monthly time step based on the observed monthly flow pattern using the "S-Curve" method described in Chapter 5 (Rim Watershed Hydrology). For ungauged watersheds, monthly flows are derived by scaling flows from a similar, but gauged watershed, by the ratio of drainage areas and the ratio of average annual precipitation depth. Both of these approaches tend to increase flow correlation between the two watersheds.

Derived streamflows may significantly depart from historical flows. Stream gauges located on the valley floor, downstream from the rim watersheds, provide a control for validating derived streamflow data for the upstream rim watersheds and making flow corrections. Once calculated, flow corrections based on a downstream control gauge could be redistributed among upstream rim watersheds. For CalSim 3.0, flow corrections were not redistributed because a single flow adjustment at the downstream control location provides greater transparency of model accuracy.

The following control gauges are located on major river system downstream from CalSim 3.0's rim watersheds and are used to calculate closure terms to correct errors in the upstream rim inflows:

- Yuba River at Smartville (USGS 11419000)
- Feather River at Oroville (USGS 11407000)
- Bear River near Wheatland (USGS 11424000)
- American River at Fair Oaks (USGS 1146500)

The Yuba, Feather, Bear and American river control gauges are located in the Sierra foothills. Components of the historical flow balance include rim watershed inflows (as calculated for CalSim 3.0), storage regulation, and stream diversions. The closure terms at these locations provide a reasonably accurate correction for errors in upstream rim watershed inflows.

Rainfall-Runoff Corrections

Surface runoff for CalSim 3.0 is calculated using the Soil Conservation Service (SCS)[3] Curve Number method (SCS method) in a continuous simulation on a daily time step. The method is described in Chapter 10 (Valley Surface Runoff). Curve numbers for different soil types and land cover were taken from typical values published by the National Resources Conservation Service (NRCS), although a limited model validation was undertaken. Long-term average annual volumes of simulated runoff may match historical average annual volumes reasonably well. However, correlation of monthly simulated runoff with monthly stream gauge data is generally poor. Similar to rim watersheds, stream gauges located on the valley floor can be used to correct poor simulation of surface runoff in CalSim 3.0. Closure terms partly correct for errors in the surface runoff because the rainfall-runoff model used to estimate historical flows for the water balance is used to estimate existing level flows for the CalSim 3.0 simulation; only the land use is different.[4] In addition to the four control gauges described in the previous section, the following control gauges are used to calculate closure terms to correct errors in surface runoff from upstream watersheds:

- Sacramento River below Wilkins Slough (USGS 11390500)
- Colusa Basin Drain at Knights Landing (DWR A02945)
- Yolo Bypass at Woodland (USGS 114530000)
- Sacramento River at Freeport (USGS 11447650)
- Sacramento River at Verona (USGS 11425500)

Flows at these 5 locations are strongly influenced not only by surface runoff from rainfall, but also groundwater inflow, irrigation diversions and return flows. In months of low or no precipitation, non-zero closure terms from a historical water balance are caused by a combination of gauge errors, inaccurate records of historical stream diversions, poor estimates of historical inflow from groundwater, and approximate estimates of historical irrigation return flows. These flow components are dynamically calculated in CalSim 3.0; errors in the historical values of these terms should not be added to the model. In contrast, in months of high precipitation, non-zero closure terms are probably predominantly caused by poor estimation of surface runoff. In these cases, including the closure term in CalSim 3.0 as a correction to the surface runoff is likely to improve model accuracy. Closure terms derived from historical flow balances are not included in CalSim 3.0 for the months of April through October; for these months precipitation is generally low and irrigation return flows are a significant fraction of the total stream flow.

Combined Rim Inflow and Rainfall-Runoff Corrections

For six water balances, flow components include both inflows from rim watersheds and inflows from rainfall-runoff. The associated downstream control points are as follows:

- Sacramento River above Bend Bridge (USGS 11377100)

[3] In 1994, the SCS changed its name to the National Resources Conservation Service (NRCS) to better reflect its expanded role of helping to protect natural resources such as water, air, plants, and animals on private and tribal lands.

[4] The closure terms do not correct for errors in the simulating effects of land-use change on runoff.

- Sacramento River at Butte City (USGS 11389000)
- Sacramento Slough at Sacramento River near Karnak (DWR A02925)
- Feather River at Nicolaus (USGS 1142500)
- Cache Creek at Yolo (USGS 11452500)
- Putah Creek near Davis (USGS 11455000)
- San Joaquin River upstream from Merced River
- San Joaquin River near Vernalis (USGS 11203500)

Closure terms associated with these locations are applied year-round or only during the non-irrigation season, depending on the relative magnitude of rim inflows to irrigation diversions and return flows, and the degree of confidence in the historical data. This is discussed in a later section.

Sources of Historical Data

The following sections briefly describe the sources of historical data used to complete the historical water budgets.

Stream-Aquifer Interaction

No data set exists for the historical interaction between the Sacramento and San Joaquin valley stream system and the underlying groundwater aquifer. To complete the historical flow balance, simulated data were used to estimate this flow component. Data were taken from the historical simulation run of California Central Valley Simulation (C2VSim) model, run 374. This version of C2VSim was publically released on March 6, 2013 (DWR, 2013)

Surface Runoff

Historical surface runoff from the valley watersheds from October 1921 through September 2015 was calculated using the rainfall-runoff model described in Chapter 5 (Valley Watershed Hydrology) and Chapter 9 (Valley Surface Runoff). Existing level land use was replaced by an annual time series of estimated historical land use for each Water Budget Area (WBA) and for each water year. Surface runoff from rice fields was calculated using historical land-use estimates and the rice water use model, modified to remove rice decomposition operations that became common practice in the early 1990s.

Stream Gauge Data

The first streamflow measurements in California were recorded during the time that William Hall was State Engineer from 1878 to 1888 (DWR, 1931). The only station maintained in the Sacramento River Basin during that period was at the mouth of the Sacramento River at Collinsville. From the early 1890s, the USGS established a network of gauges throughout the State. However, observations were made only on the major rivers. The first gauge upstream from the Delta was established in 1895 at Jellys Ferry on the Sacramento River.[5] In 1903, the USGS expanded its network of gaging stations in California to over 200 in number. Table 33 of Bulletin 5, (DWR, 1923) lists USGS reports published between 1898 and 1921 that contains some of the earliest recorded California stream flow data. The *Index to Sources of Hydrologic Data*, Bulletin 230 (DWR, 1985), contains a comprehensive list of hydrologic data stations throughout the State as of 1981.

Historical streamflow data for CalSim 3.0 are primarily taken from USGS and DWR, supplemented by data from local water districts and agencies.

USGS Water Supply Papers

Through September 1960, USGS published streamflow records in an annual series of water supply papers titled *Surface Water Supply of the United States*. The records for California are contained in Parts 9, 10, and 11 of that series. Beginning with the water year 1961, streamflow records and related data for California were released in an annual series of reports on a State-boundary basis. Originally titled *Surface Water Records for California*, the series was renamed *Water Resources Data, California* in 1965. In 1971, USGS, in cooperation with DWR, also published summary data for California and adjacent areas for each year of record through September 1968 in Bulletin 130, *California Streamflow Characteristics*.

Surface water records from the USGS water supply papers extend back to 1899. Annual reports from 1991 to present are available online (USGS, 2016a). Streamflow records for California also are available online (USGS, 2016b). A more complete set of USGS streamflow records is available from CD-ROM published by Hydrosphere Data Products compiled from the USGS WATSTORE database.

California Data Exchange Center

The California Data Exchange Center (CDEC), maintained by DWR, contains real-time and historical hydrologic data gathered by Federal, State, and other cooperating agencies. Presently, there are over 800 operational recording stations in California. Data are available online (CDEC, 2016).

Water Data Library

The Water Data Library, maintained by DWR, contains historical hydrologic data collected by DWR and cooperating agencies and previously made available in several print series. The data library contains time series hydrologic data in three categories:

- **Surface water data** – 300 surface water flow and stage monitoring sites
- **Water quality data** – 1,500 water quality monitoring sites
- **Groundwater level data** – groundwater level data and hydrographs for more than 35,000 wells

[5] The Jellys Ferry gauge was moved downstream in 1902 to the Sacramento River near Red Bluff (USGS 11378000).

Surface water records published on the Water Data Library website have been reviewed and checked by DWR staff. The Water Data Library is preferred to CDEC as a source of data.

Diversion Data

Historical diversion data are available from many different sources, including DWR bulletins, Reclamation reports and records, and local water agencies and districts. The following sections briefly discuss these sources.

Bulletin 23, Report of Sacramento-San Joaquin Water Supervisor

Bulletin 23 was published continuously between 1930 and 1965 (DWR, 2016a). Between 1930 and 1935 the Bulletin was titled *Report of the Sacramento-San Joaquin Water Supervisor*. In 1936, the title was changed to *Sacramento-San Joaquin Water Supervision*, and in 1959 the title became *Surface Water Flow*. The first bulletin was published in 1930 by the Office of the Water Supervisor of the Division of Water Resources and presented data on diversions, streamflow, return flow, water use and salinity in the Sacramento and San Joaquin River system for water years 1924 through 1928. The scope of the series was broadened in Bulletin 23-56 to include additional data for stream and river systems. The series was discontinued in 1965, following the publication of Bulletin 23-62. Table 16-1 presents a complete list of the series.

Table 16-1. Bulletin 23 Series

Bulletin	Year Reported	Publication Date		Bulletin	Year Reported	Publication Date
23	1924-1928	1930		23-46	1946	Jun-47
23-29	1929	Jul-30		23-47	1947	Jun-48
23-30	1930	Jul-31		23-48	1948	May-49
23-31	1931	Aug-32		23-49	1949	Jun-50
23-32	1932	Jun-33		23-50	1950	Oct-51
23-33	1933 – 1934	Jun-35		23-51	1951	Oct-52
23-35	1935	Jun-36		23-52	1952	Nov-53
23-36	1936	May-37		23-53	1953	Oct-54
23-37	1937	Jul-38		23-54	1954	Aug-55
23-38	1938	Apr-39		23-55	1955	Jun-57
23-39	1939	Jun-40		23-56	1956	Jan-59
23-40	1940	Jun-41		23-57	1957	Feb-60
23-41	1941	Jun-42		23-58	1958	Dec-60
23-42	1942	Jul-43		23-59	1959	May-61
23-43	1943	Jun-44		23-60	1960	Sep-61
23-44	1944	Jun-45		23-61	1961	Aug-63
23-45	1945	Jun-46		23-62	1962	Jul-65

Bulletin 130, Hydrologic Data

Bulletin 130 superseded Bulletin 23 and presented hydrologic data in five appendices covering the entire State. The information, formerly presented in Bulletins 23, 39, 65, 66, and 77, includes data on climate, surface water flow, and quality, and groundwater measurements and quality. The bulletin was published annually from 1963 through 1975 and was last published in 1988 (DWR, 2016b). Table 16-2 presents a complete list of the series.

Table 16-2. Bulletin 130 Series

Bulletin	Year Reported	Publication Date	Bulletin	Year Reported	Publication Date
130-63	1963	Apr-65	130-70	1970	Apr-72
130-64	1964	May-66	130-71	1971	Dec-72
130-65	1965	Dec-66	130-72	1972	Dec-73
130-66	1966	Dec-67	130-73	1973	Dec-74
130-67	1967	May-69	130-74	1974	Mar-76
130-68	1968	Sep-70	130-75	1975	May-77
130-69	1969	May-71	130-85	1985	May-88

Historical Return Flows

Within the Sacramento Valley, a large portion of irrigation return flow follows troughs in the basins on either side of the Sacramento River and discharges to the river through well-defined channels at a considerable distance downstream from the diversion source. Historical flow data exist for many of these drainage channels, including the following:

- Reclamation District (RD) 1500 drain
- Butte Slough
- RD 70 drain
- RD 108 drain at Rough and Ready Bend
- Colusa Basin Drain at State Highway 20 and at Knights Landing outfall gates
- Sacramento Slough (which conveys RD 1500 drain water combined with drainage from the east and west borrow pits of the Sutter Bypass)
- RD 1000 drain (Pritchard Lake, Second Bannon Slough)
- Conaway Ranch drain
- Back borrow pit of RD 1000 (East Main Drain)
- RD 1600 drain

Elsewhere in the Sacramento Valley and for most of the San Joaquin Valley, return flow channels are less well defined and irrigation return flows are estimated from summer accretions between river gauges on the San Joaquin River and gauges on the eastside tributaries.

Where gauge records are not available, historical irrigation return flows were estimated based on estimated historical applied water demands and water use factors. Irrigation return flows are calculated as the tailwater, less any reuse, augmented by canal operational spills and canal lateral flow to canal toe drains. Tailwater was calculated using CalSim Hydro and historical crop acreage. Initially, water use factors were based on values established for current practices. Operational spills and canal lateral flows were expressed as a fraction of the historical diversions. Water use factors subsequently were adjusted to increase return flows in the water year 1922 by up to 10 percent, diminishing to no increase for the water year 2015.

Historical Flows at Control Points

The following sections describe available streamflow data for the various CalSim 3.0 control points and describe methods for completing the historical record when monthly observed data are not available.

Sacramento River at Shasta Dam

Sacramento River at Shasta Dam (model node SHSTA) is not a model control point, but is an important gauge location within the Sacramento Valley. Rim inflows to Shasta Lake account for approximately 28 percent of the total rim inflows. Shasta Dam was constructed between September 1938 and June 1945. Storage of water in Shasta Reservoir began in December 1942. The project was placed in full operation in April 1949. Historical monthly releases from Shasta Dam, starting December 1942, are available from Reclamation's reservoir report of operations.

From November 1925 through November 1942, USGS maintained a gauge for the Sacramento River at Kennett (USGS 11369500), located approximately 2 miles upstream from the Shasta Dam site. Monthly flow records are published in Table 1 of the *1957 Joint Hydrology Study* (DWR, 1958). Table 3 of the same report contains estimated monthly flows at the Shasta Dam site for water years 1922 through 1954. Flows before October 1942 were computed as the estimated or recorded flow of the Sacramento River at Kennett, plus 2.5 percent of the river accretion between Kennett and the Red Bluff gauge (USGS 11378000). Before December 1925, flows at Kennett were estimated from a flood warning gauge at Kennett operated by the U.S. Weather Bureau. Flows at Kennett for October 1925 were estimated from USGS unpublished data.

In 2007, historical flows for Sacramento River at Shasta Dam were reestimated by CH2M HILL. Between October 1921 and September 1925, the flow at Kennett was estimated as the sum of three upstream gauges, multiplied by a scaling factor. The upstream gauges were Sacramento River at Antler (USGS 11342500), McCloud River at Baird (USGS 11369000), and the Pit River near YdalPom (USGS 11366500). The scaling factor of 1.0464 is the ratio of the combined flow at the upstream gauges to the observed flow at Kennett for the common period of record, October 1925 to September 1941 (CH2M HILL, 2007). From October 1938 through December 1943, the flow at Shasta Dam was assumed to be equal to the measured flow at Keswick (USGS 11370500). The revised flows before October 1925 determined by CH2M HILL are significantly greater than flows published in the *1957 Joint Hydrology Study* and are less consistent with gauge records for the Sacramento River near Red Bluff. Data from the three upstream gauges are considered unreliable. Therefore, CalSim 3.0 has adopted the methodology of the *1957 Joint Hydrology Study* (DWR, 1958). Flows before October 1925 are taken directly from Table 1 of this study. From October 1925 through September 1942, flows are calculated as the sum of the flows at Kennett plus 2.5 percent of the river accretion between the Kennett and Red Bluff gauges.[6] From October 1942 through December 1943, flows are calculated as the sum of the flows at Keswick less 1.8 percent of the river accretion between the Keswick and Red Bluff gauges.[7] Beginning in January 1944, flows are from the reservoir report of operations.

Simulated inflows to Shasta Lake are set equal to historical flows at this location.

Sacramento River above Bend Bridge

Gauged flows for the Sacramento River as it flows out of the Redding basin are available beginning in October 1902. Before October 1968, the gauge (USGS 11378000) was located approximately 7.3 miles downstream from Bend Bridge at Sacramento River near Red Bluff. Measured flows included flows from Paynes Creek and adjacent smaller watershed (Sevenmile Creek). The gauge was relocated in October 1968 to its present location to avoid backwater effects from Red Bluff Diversion Dam and subsequently renumbered. The gauge (USGS 11377100) is now located on the left bank of the river, approximately 2.7 miles upstream from Bend Bridge, 7.7 miles upstream from the mouth of Paynes Creek, and approximately 8.1 miles northeast of the City of Red Bluff.

For CalSim 3.0, outflow from the Redding basin is based on observed or estimated flows for the Sacramento River above Bend Bridge (model node SAC257). Flow records are available at this location, starting in October 1968. For CalSim 3.0, flows above Bend Bridge before October 1968 are estimated as the historical flows for the Sacramento River near Red Bluff less 1.10 times the flow of Paynes Creek near Red Bluff (USGS 11377500).[8,9] Measured flows for Paynes Creek are available from October 1949 through September 1966. Observed flows for Paynes Creek were extended through correlation with observed flows for Mill Creek near Los Molinos (USGS 11381500).

Sacramento River at Butte City

Gauge data for the Sacramento River at Butte City (model node SAC169) are available beginning in April 1921. The gauge was originally maintained by USGS (11389000), but since October 1998 has been maintained and operated by DWR (A02500). The gauge is currently located on the left bank, 100 feet upstream from the State Highway 162 Bridge. Before December 1930, the gauge was located approximately 0.5 miles upstream from the bridge. Before October 1938, only low flows during the summer months (May through October) were recorded. These low flows are reported in the Bulletin 23 series and USGS water supply papers. For water years 1996 and 1997, only water stage data are available.

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[6] The factor of 2.5 percent is calculated as the difference in upstream drainage area between Sacramento River at Shasta Dam (6,421 square miles) and Sacramento River at Kennett (6,355 square miles) divided by the difference in upstream drainage area between Sacramento River at Red Bluff (9,020 square miles) and Sacramento River at Kennett (6,355 square miles).

[7] The factor of 1.8 percent is calculated as the difference in upstream drainage area between Sacramento River at Keswick (6,468 square miles) and Sacramento River at Shasta Dam (6,421 square miles) divided by the difference in upstream drainage area between Sacramento River at Red Bluff (9,020 square miles) and Sacramento River at Keswick (6,468 square miles).

[8] The factor of 1.10 accounts for the ungauged flow contribution from Sevenmile Creek. The factor was determined based on relative drainage areas and average annual precipitation. This factor was previously determined as 1.12 for CalSim II.

[9] Published data (USGS 11378000) for September 1933 was found to be in error due to an apparent data error for flow in one particular day.

Four flood relief structures are located upstream from the Butte City gauge, at the upstream end of the left (east) bank levee of the Sacramento River Flood Control Project. The M&T and 3B's flood relief structures are located upstream from DWR's Ord Ferry gauge (A02570); the Goose Lake Flood Relief Structure is located between the Ord Ferry and Butte City gauges. If these three structures fail, a raised 6,000-foot-long roadway near the south end of Llano Seco allows excess flood waters to spill into the Butte basin before being confined by the downstream project levees. Total flow for the Sacramento River at the latitude of Butte City is the sum of the Sacramento River at Butte City and flood spills at these four locations to the Butte basin.

For CalSim 3.0, historical flows for the Sacramento River at Butte City are taken from USGS and DWR records. Flows before October 1938 were taken from Table 5 of the *1957 Joint Hydrology Study* (DWR, 1958). For months where no data are available from Table 5, flows were taken from Table 62 which provides an estimate of the combined flow of the Sacramento River at Butte City and left bank overflow above Butte City to the Butte basin.

Only stage data are available from July 1995 through September 1997. For this period, flows were estimated as the Sacramento River flow at Ord Ferry (A02570) less agricultural diversions by Provident Irrigation District (ID) and Princeton-Cordova-Glenn ID.

Sacramento River below Wilkins Slough

Wilkins Slough is located on the mainstem of the Sacramento River upstream from the Colusa Basin Drain outfall and upstream from the confluence of the Sacramento and Feather rivers. The river reach from Wilkins Slough to Knights Landing usually conveys the least amount of flow. Originally, a minimum flow standard of 5,000 cubic feet per second (CFS) was established to facilitate river navigation upstream as far as Chico Landing. However, since the construction of the Sacramento Deep Water Ship Channel, maintaining conditions for commercial navigation is no longer a concern on the lower Sacramento River. The flow standard served as the basis for the design of many irrigation pumping stations on the upper Sacramento River. Diverters are able to operate for extended periods for flows of 4,000 CFS below Wilkins Slough, but pumping operations become severely affected below this flow. The Central Valley Project (CVP) usually releases water from Shasta Lake to meet minimum flow criteria below Wilkins Slough. Accurate simulation of flows in the reach from Wilkins Slough to Knights Landing is needed to represent these operations.

Flow in the Sacramento River below Wilkins Slough, (model node SAC120) is based on the USGS gauge below Wilkins Slough near Grimes (USGS 11390500). The gauge is located 1,200 feet downstream from Wilkins Slough, approximately 5.8 miles southeast of the town of Grimes. Immediately upstream from the gauge, RD 108 diverts water at its Wilkins Slough Pumping Plant. Flow records for the gauge are available starting August 1931. However, before October 1938, only data for low-flow months (mid-April through October) were recorded. Moulton, Colusa, and Tisdale weirs are located between the Butte City and Wilkins Slough gauges. Tisdale Weir is the first of these weirs to spill; discharge begins when Sacramento River flow exceeds about 23,000 CFS.

For CalSim 3.0, before October 1938, flows in the Sacramento River below Wilkins Slough are calculated using the estimated flow of the Sacramento River at Knights Landing, less flow from the Colusa Basin Drain outfall, plus Sacramento River diversions between Wilkins Slough gauge and the drain outfall. Historical diversions include those by RD 108, River Garden Farms, and Sutter Mutual Water District (WD). Historical flows for the Sacramento River at Knights Landing are from the *1957 Joint Hydrology Study* (DWR, 1958). Table 8 of the report provides a partial estimate for the historical flow for the Sacramento River for water years 1922 through 1954. Missing values were in-filled based on Table 66 of the same report, which estimates the flow of the Sacramento River at the latitude of the mouth of the Colusa Basin Drain (not including flow in Butte Creek, Reclamation Drain 1500, and Wadsworth Canal). Bank overflows and weir spills were subtracted from the Sacramento River at the latitude of the mouth of the Colusa Basin Drain to obtain flows for the Sacramento River above the drain outfall. Estimates of bank overflow above Butte City were taken from Table 42 of the *1957 Joint Hydrology Study* (DWR, 1958). Flows over the Moulton, Colusa, and Tisdale weirs were taken from Tables 43, 44, and 45 of the same report. No records are available for flood flows through the Moulton Break before the construction of Moulton Weir in 1932. Similarly, no records are available for flood flows passing through DeJarnett Break before the construction of Colusa Weir in 1933.

Colusa Basin Drain at Knights Landing Outfall Gates

The Knights Landing Outfall Gates[10] (model node CBD000) are located within the right bank levee of the Sacramento River, approximately 0.3 miles upstream from the mouth of the Colusa Basin Drain. The drain conveys surface runoff from precipitation and irrigation return flows from the Colusa basin either to the Sacramento River or through the Knights Landing Ridge Cut to the Yolo Bypass. The amount of water flowing through the Knights Landing Ridge Cut depends on irrigation needs, stage in the Sacramento River, drain flow rate, and setting at the Wallace Weir, located at the confluence of the Knights Landing Ridge Cut and Yolo Bypass. The Knights Landing Outfall Gates reduce the flood risk to the lower Colusa basin from Sacramento River backwater, and also provide drainage to the Sacramento River during low-flow periods. During the irrigation season, the amount of flow entering the Knights Landing Ridge Cut is controlled by the outfall gates and the Wallace Weir. DWR operates the outfall gates to maintain water levels for irrigation purposes in both the lower Colusa Basin Drain and Knights Landing Ridge Cut upstream from the Wallace Weir. During winter months, the Wallace Weir is removed and the Knights Landing Ridge Cut operates as a flood channel. When flow in the Sacramento River is above 25,000 CFS, drain water can no longer discharge through the outfall gates because of the high river stage and must flow through the Knights Landing Ridge Cut to the Yolo Bypass, which is designed to convey approximately 20,000 CFS. DWR operates a gauge (A02945) immediately upstream from the Knights Landing Outfall Gates. Data are available beginning in June 1924. However, for water years 1924 through 1939 flows were typically only recorded from May through October. [11]

[10] Also known as the Sycamore Slough Outfall Gates.

[11] From 1924 through 1939, values published in DWR Bulletin 21 include the flow of Sycamore Slough to the Colusa Basin Drain. Sycamore Slough enters the Colusa Basin Drain downstream from the Colusa Basin Drain Outfall Gates. Beginning in January 1940, Bulletin 23 separately published flows recorded by gauge A02945and flows entering the drain from Sycamore Slough. CalSim 3.0 represents flows in Sycamore Slough as discharging to the Sacramento River at the mouth of the Colusa Basin Drain. Before January 1940, historical flows for the Colusa Basin Drain at Knights Landing include flows from Sycamore Slough. Beginning in 1940, historical flows for the Colusa Basin Drain at Knights Landing do <u>not</u> include flows from Sycamore Slough.

For CalSim 3.0, historical monthly flows are from DWR gauge A02945.[12] For water years 1922 through 1954, missing gauge data were filled with data from Table 37 of the *1957 Joint Hydrology Study* (DWR, 1958). Flows for October 1921 through November 1923 are assumed equal to the 18-year mean for water years 1924 to 1941.

From February 1987 to September 1987, no flow data were recorded because of construction activities at the outfall gates. Values for these months were taken from previous work undertaken by DWR's Bay-Delta Office. Similarly, missing data for November 1958, November 1963, April 1968, June 1969, and September 1969 were taken from previous work. Partial data for February 1982, June 1989, August 1989, September 1989, December 1989, January 1992, February 1992, October 1993, November 1993, December 1993, and October 2000 were in-filled by linear interpolation of daily data. No data were recorded for the water year 2005. Flows were estimated from the measured flows in the Colusa Basin Drain at Highway 20 (DWR A02976).

Sacramento River at Verona

Flow in the Sacramento River at Verona (model node SAC083) includes inflows from the Colusa basin, Sutter basin, and Feather River basin. Flood flows entering the river through the Sutter Bypass are subsequently discharged over the Fremont Weir. USGS has operated a gauge (11425500) at Verona since October 1928. The gauge is located approximately 1.0 mile downstream from the confluence with the Feather River and immediately below the mouth of the Natomas Cross-Canal. Flows during the low-flow months (March through October) are reported in Bulletin 23, starting the water year 1924.

For CalSim 3.0, historical flows for the Sacramento River at Verona from October 1921 through September 1945 were initially taken from the 1957 Joint Hydrology Study (DWR, 1958). The flow at Verona from October 1946 through September 2015 is from USGS records. Monthly flow data for the Sacramento River at Verona were checked by correlation with rim station inflows above Verona. In several months, historical data for the flow at Verona, when combined with records for Fremont Weir spills, are inconsistent with the combined inflows of the Sacramento River above Red Bluff, Feather River inflow to Lake Oroville, Yuba River at Smartville, and the Bear River at Wheatland Bear. Gauge corrections, estimated by DWR planning staff in November 1987, were applied to the historical data before October 1929. It is not known whether these corrections took into account flood storage adjustments that are described later in this section.

Sacramento River at Freeport

The Sacramento River at Freeport (model node SAC049), when combined with return flows from the Sacramento Regional Wastewater Treatment Plant (WWTP), and flows in the Yolo Bypass downstream from the Putah Creek confluence, represents total inflow to the Delta from

[12] Gauge data from June 1924 through September 1975 are from Bulletin 21 and Bulletin 130. Data from October 1975 through September 1983 are from DWR's Water Data Library. Beginning in October 1983, data are from Pat Huckabay, DWR Northern District (personal communication, March 23, 2011). During a 2011 review of the equations used to compute discharge for Colusa Basin Drain at Knights Landing (A02945), as well as field surveys to check the datum of the staff gauges, some minor errors were found in previous flow estimates. Subsequently, Huckabay revised flows for water years 1982 through 2010.

the Sacramento Valley. The historical flow record is based on gauged flows for the Sacramento River at Freeport and the Sacramento River at Sacramento (I-Street Bridge).

The gauge for the Sacramento River at Sacramento (USGS 11447500) was for many years regarded as the most important gauge in the Federal-State network of stream gauges, being the most downstream flow measurement station upstream from the Delta. River stage at the City of Sacramento is affected by tidal influence for river flows less than 35,000 CFS. Flow measurements date back to 1879. Historical flows are reported in Bulletin 23, starting 1924. The Sacramento gauge has been sited at various locations in the vicinity of the I-Street Bridge. Between November 1956 and September 1979, the gauge was located on the left bank, 1,000 feet upstream from the I-Street Bridge, approximately 0.5 miles downstream from the mouth of the American River. In October 1979, the Sacramento River gauge was relocated downstream and renamed Sacramento River at Freeport (USGS 11447650).

The USGS gauge at Freeport is located on the Freeport Bridge approximately 11 miles south of Sacramento. It is a short-range acoustic Doppler velocity meter with an upward-looking stage sensor. Records are available from October 1979 to present, except for the water year 2005, which is missing.

For CalSim 3.0, monthly flows for the Sacramento River at Freeport for water years 1922 through 1948 are based on Table 10 of the *1957 Joint Hydrology Study* (DWR, 1958). As stated in this study, monthly flows for water years 1922 and 1923 and the November through March flows for water years 1924 through 1939 were estimated as the Sacramento River at Verona, adjusted for accretions and diversions between Sacramento and Verona. Before 1934, values published in the *1957 Joint Hydrology Study* were adjusted to account for apparent discrepancies between published flows and the combined flows of the Sacramento River above Red Bluff, Feather River at Oroville, Yuba River at Smartville, and Bear River near Wheatland. These adjustments, made by DWR staff, date back to the 1960s.[13] Starting in October 1948, historical flows for the CalSim 3.0 hydrology are from the USGS gauges at Sacramento and subsequently at Freeport.[14]

Feather River at Oroville

Since 1967 flows in the lower Feather River have been controlled by Oroville Dam (model node OROVL), one of the principal features of the State Water Project (SWP). Flows in the West Branch Feather River, and North, Middle, and South Forks Feather River combine at Lake Oroville. Water is released for power generation and downstream water supply.

Historical records for the Feather River near Oroville (USGS 11407000)[15] are available starting October 1901. Before October 1934 the gauge was located just below the Mountain Boulevard highway bridge. From October 1934 through June 1962, the gauge was located just below the

[13] No documentation for these adjustments were found. However, for consistency with CalSim II, these adjustments have been maintained.

[14] Flows for water year 2009 are from EarthInfo. Flows for water year 2005 are from CDEC (station ID FPT). Missing data for July 2005 and August 2005 was estimated by linear interpolation of daily flows between July 10, 2005, and September 1, 2005.

[15] For water years 1935 through 1960, flows were published as "near Oroville."

Oroville Dam site. From July 1962 through September 1964 the gauge was located 200 feet below the Mountain Boulevard highway bridge. Since January 1964, the gauge has been located 300 feet above the Fish Barrier Dam. In its current location, the gauge measures flow in the low flow channel and excludes dam releases that are diverted upstream from the gauge to the Power Canal and the Thermalito Complex.

Storage in Lake Oroville began October 1967, as a result, measured flows at the USGS gauge (11407000) are impaired by storage regulation in Lake Oroville and exclude diversions to the Thermalito complex. However, from October 1967 through September 1970, USGS also report gauge flows adjusted for Oroville-Thermalito operations. Beginning in October 1968, USGS reports the combined river flow in the low flow channel and the upstream diversion to the fish hatchery (USGS 11406930), which returns to the river.

For the CalSim 3.0 hydrology, flows for the Feather River at Oroville before October 1970 are from USGS records. Beginning in October 1970, inflows to Lake Oroville are from SWP's reservoir report of operations.

Feather River at Nicolaus

Flows in the Feather River at Nicolaus (model node FTR008), 3 miles below the mouth of the Bear River, are approximately equal to the Feather River outflow to the Sacramento River. Summertime diversions from the Feather River downstream from the gauge location are of the order of 13,000 acre-feet (DWR, 1978). Inflows to the river are limited by the flood levee system. For many years USGS operated a gauge at Nicolaus. Records began October 1920. The gauge was originally located at the old State Highway 99 (Garden Highway) Bridge at Nicolaus (RM 9.7). In October 1973 the gauge was relocated to the new State Highway 99 Bridge at Nicolaus (RM 9.4). In October 1974, the gauge was relocated a second time to approximately 1.3 miles below the Highway 99 Bridge at RM 8.1. The gauge was discontinued in September 1983. DWR assumed operation in 1986 and monitors stage data only. The station (DWR A05103) is operated as a flood control warning station and monitored by CDEC. Low-water flows for the USGS gauge were first published in June 1921. Complete annual records are available from October 1943 through September 1983.

For CalSim 3.0, historical flows for the Sacramento River at Verona from October 1921 through September 1943 were taken from Table 14 of the *1957 Joint Hydrology Study* (DWR, 1958). Missing historical flows were calculated for the *1957 Joint Hydrology Study* through correlation with the combined flow of the Feather River at Oroville, Yuba River at Smartville, and the Bear River near Wheatland. From October 1943 through September 1983, flows were taken from the gauge Feather River at Nicolaus (USGS 11425000). Beginning in October 1983, flows for the Feather River at Nicolaus were estimated through correlation with the sum of the flows for the Feather River at Gridley, Yuba River near Marysville, and the Bear River near Wheatland.[16] The

[16] The main sources of accretions between the 3 upstream gauges and the site of the discontinued gauge at Nicolaus are inflows from Honcut Creek, irrigation return flows from lands on the left bank of the Feather River, return flows from the Cox Spill, and groundwater accretions. There are irrigation diversions at the Sunset Pumps by Sutter Extension WD, and downstream diversions by the City of Yuba City, Feather WD, Oswald WD, Tudor MWC, Garden Highway MWC, and Plumas MWC.

stretch of the Feather River between the Gridley and Nicolaus gauges is approximately 43 miles long. Data developed for the correlation are described below.

- Data are available for the Feather River at Gridley (USGS 11407150) beginning in October 1968. Flows at this location were also calculated from mass balance using the Feather River at Oroville, agricultural diversions to Western Canal and the Joint Board Water District, municipal diversions by South Feather Water and Power Agency (Palermo Canal), Thermalito ID and CalWater – Oroville, storage regulation in Thermalito Forebay and Afterbay, and associated evaporative losses, and return flows from the Kelly Ridge Powerplant. The line of linear regression of observed flows against calculated flows at Gridley has a coefficient of determination (r^2) of 0.9997. The regression equation was used to extend the Gridley data back to October 1921.

- Data are available for the Yuba River near Marysville (USGS 11421000) beginning in October 1968. Flows at this location were also calculated from mass balance using the flow for the Yuba River at Smartville and agricultural diversions to Brown Valley ID and Yuba County Water Agency (WA) Member Agencies through the North and South canals. The line of linear regression of observed against calculated flows for the Yuba River near Marysville has an r^2 value of 0.989. The regression equation was used to extend the Marysville gauge data back to October 1921.

- Data available for the Bear River near Wheatland are described in a separate section.

Two sets of variables were developed: (1) sum of Feather River at Nicolaus and irrigation diversions along the Feather River between Gridley and Nicolaus; and (2) sum of gauged or estimated flows for the Feather River at Gridley, Yuba River near Marysville, and Bear River near Smartville. The line of linear regression between these parameters has an r^2 value of 0.996 for water years 1968 – 1983 and has an r^2 value of 0.989 for water years 1943 – 1963. The former linear regression relationship was used to develop monthly flows for the Feather River at Nicolaus beginning in October 1983.[17]

Sacramento Slough near Karnak

The Sutter Bypass runs northwest to southeast, bisecting Sutter County, and separating the Sutter basin from the lower Feather River basin. It consists of two levees set approximately 4,000 feet apart and associated channels, known as the East and West Borrow canals, on the inside of the levees. The bypass is an important flood-relief channel providing overflow for the Sacramento River during the high stage. The bypass also supports agriculture and extensive wetlands. Water enters the Sutter Bypass from three directions, as follows:

- Floodwaters from Butte basin and flows in Butte Creek enter Butte Slough and subsequently the bypass from the north.

[17] An attempt was made to construct historical flows using daily gauge data for DWR gauge A05103, Feather River near Nicolaus. Although the results are generally consistent with flows estimated using a regression equation and upstream gauge data, it was apparent that the USGS rating curve was no longer valid, and that flows for the same stage have significantly increased since 1983.

- When the Sacramento River is at flood stage, water enters the bypass from the west, spilling at Tisdale Weir and flowing through the Tisdale Bypass. Additional water enters the West Borrow Canal through agricultural return flows from RD 1500 and RD 1660.
- The East Borrow Canal collects both direct runoff and agricultural return flow from lands to the east, located between the Feather River and Sutter Bypass. Excess water is conveyed to the East Borrow Canal through the Snake River, Wadsworth Canal, Gilsizer, Willow, and Nelson sloughs and State Pumping Plants 1, 2, and 3.

The East Borrow Canal joins the West Borrow Canal downstream from Willow Slough and water flows through the Sacramento Slough to the Sacramento River.

Flows associated with the Sutter Bypass are measured at various locations. The Butte Slough near Meridian gauge (DWR A02972) is located upstream from the East-West Borrow Canal split. The Wadsworth Canal near Sutter gauge (DWR A05929) measured inflows from the Wadsworth Canal to the East Borrow Canal. However, this gauge was decommissioned in 1996. The Willow Slough gauge, downstream from Weir No. 2 measures flow from the East Borrow Canal to the West Borrow Canal. Outflows from the Sutter Bypass are measured at the Sacramento Slough near Karnak (DWR A02925).

For the CalSim 3.0 hydrology, flows for the Sacramento Slough near Karnak (model node SSL001) are based on the DWR gauge. The gauge is located on the right bank of the slough, 0.5 miles above the mouth, and 4.6 miles southeast of the town of Knights Landing. During low flows, the gauge measures the combined flows of Sutter Bypass and the RD 1500 drain. During high stage above 26.0 feet elevation, the slough is entirely flooded. Flow data for low-flow months are available beginning in May 1924. However, before the water year 1939, the gauge was only operated during the irrigation season (DWR, 1993).

Before October 1975, monthly flow data for Sacramento Slough near Karnak were taken from *Butte and Sutter Basins* (DWR, 1993). Beginning in October 1975 daily flow data were obtained from DWR’s Water Data Library. For months when the Sacramento River was below flood stage, and weir spills to the Sutter and Butte basins were zero, missing gauge data were infilled using average monthly gauged flows for non-flood months. Flows during the flood months were set equal to the sum of flood spills to the Butte and Sutter basins, outflow from Butte Creek, and outflow from the Wadsworth Canal.

Yuba River at Smartville

The Yuba River basin includes the North, Middle and South Forks of the Yuba River. These watersheds have been extensively developed for hydroelectric power generation and consumptive uses by Yuba County WA, Nevada ID, and Pacific Gas & Electric Company (PG&E). Storage facilities on the Middle Yuba and South Yuba rivers and associated diversion facilities enable these entities to export a combined average of approximately 400,000 acre-feet per year from the Yuba River basin to the Bear River and American River basins. In addition, the South Feather Water and Power Agency exports an average of approximately 70,000 acre-feet per year from Slate Creek (a tributary to the North Yuba River) to the Feather River basin. As part of the Yuba River Development Project, Yuba County WA owns and operates New Bullards Bar Dam on the North Fork Yuba River for water supply and power generation. Englebright

Dam, located downstream from New Bullards Bar Dam was constructed in 1941 to capture sediment produced by upstream hydraulic mining activities. Englebright Reservoir receives inflows from both the Middle and South Yuba rivers.

The lower Yuba River refers to the 24-mile-long section of the river between Englebright Dam and its confluence with the Feather River southwest of the City of Marysville. Deer Creek flows into the Yuba River at approximately RM 23. Dry Creek flows into the Yuba River at RM 14, approximately 2 miles upstream from Daguerre Point Dam. Flow in Dry Creek is regulated by Browns Valley ID's operation of Merle Collins Reservoir, which is located on Dry Creek about 8 miles upstream from the creek's confluence with the Yuba River. Water is diverted from the lower Yuba River by Browns Valley ID and at Daguerre Point Dam by Yuba County WA.

The Yuba River at Smartville (model node YUB023) is a measure of total water available in the lower Yuba River for irrigation purposes and for instream flow requirements. Flows for the Yuba River at Smartville were measured for water years 1922 through 1941(USGS 11419000). The gauge was located approximately 1 mile downstream from Deer Creek. The gauge was discontinued in September 1941 and a new gauge installed upstream, Yuba River below Englebright near Smartville (USGS 11418500). The latter gauge is located approximately 2,000 feet below Englebright Dam, and 0.5 miles upstream from Deer Creek. Before October 1953, records were published as "Yuba River at Narrows Dam."

For CalSim 3.0, flows for the Yuba River at Smartville are from USGS records. From October 1941 through September 2015, flows are calculated as the sum of the Yuba River below Englebright near Smartville and Deer Creek near Smartville (USGS 11418500). The Deer Creek gauge is located approximately 0.9 miles upstream from the mouth of the creek. Flows in Deer Creek are affected by imports from the South Yuba Canal, storage regulation in Scotts Flat Reservoir (since 1949), and upstream diversions by Nevada ID.

Bear River near Wheatland

The Bear River has been extensively developed for water supply and power generation, with significant flows exported from the watershed to the American River basin. Flows are regulated by Rollins Dam (since December 1964), Combie Dam (since June 1928), and Camp Far West Dam (since October 1963).[18] Bear River flows above Camp Far West Dam are largely controlled by Nevada ID and PG&E. Approximately, 200,000 acre-feet of water annually are imported from Lake Spaulding on the South Fork of the Yuba River through the Drum Canal system; supplemented by minor imports from North Fork of the North Fork American River. Most of this water is rediverted from the Bear River by these two agencies. Immediately downstream from Camp Far West Dam, South Sutter WD and Camp Far West ID divert water for agricultural purposes.

The Bear River near Wheatland gauge (model node BRR011) is located downstream from all river diversions and storage regulation and, when combined with local inflows from Dry Creek and Yankee Slough, represent the total outflow to the Feather River. For water years 1922 through 1927, Bear River flows were measured by the gauge at Van Trent (USGS 11423500).

[18] New Camp Far West Dam replaced the original 5,000 acre-foot dam and reservoir, which was completed in 1928.

The gauge was located just above the present location of Camp Far West Dam. Records for the existing gauge, Bear River near Wheatland (USGS 11424000), begin in October 1928. The gauge is located 100 feet downstream from the Highway 99 bridge, and approximately 6.4 miles downstream from Rock Creek.

Historical monthly values for the CalSim 3.0 hydrology are mostly from USGS records. From October 1921 through September 1927, flows are from the Van Trent gauge, multiplied by a factor of 1.05 to account for accretions between the Van Trent and Wheatland gauge locations.[19] From October 1927 through December 1927, flows are from Table 18 of the *1957 Joint Hydrology Study* (DWR, 1958). Values from January 1928 through October 1928 were estimated by M. Roos (DWR, 1965).

American River at Fair Oaks

The American River basin is divided into the upper watershed above Folsom Dam, and the lower watershed, consisting primarily of the 29-mile-long river reach between Folsom Dam and the river's confluence with the Sacramento River. The upper watershed has been developed for both power generation and water supply. Upstream developments include Placer County WA's Middle Fork Project, Sacramento Municipal Utility District's (SMUD) Upper American River Project and El Dorado ID's Project 184.

There is a long flow record for the American River at Fair Oaks (model node AMR022). Records for the gauge at Fair Oaks (USGS 11446500) began in November 1904. The gauge is located 2,100 feet downstream from Nimbus Dam. Flows at the gauge are affected by extensive hydropower developments and storage regulation on the Middle and South Fork of the American River, upstream diversions by Placer County WA and El Dorado ID, and by PG&E imports from the Bear River through the South Canal. Beginning in February 1955, river flows have been regulated by Folsom Dam. There are major diversions for M&I purposes from both Lake Folsom and Lake Natoma.

The historical flow record for the CalSim 3.0 hydrology is directly from USGS records.

Stony Creek below Black Butte

After Cottonwood Creek, Stony Creek is the largest tributary to the Sacramento River on the westside of the valley. The watershed has been developed for both flood control and water supply. For the purposes of CalSim 3.0, the watershed is divided into the upper Stony Creek watershed and the lower Stony Creek watershed, with Black Butte Dam and its associated ridge line forming the boundary between the two watersheds. The upper watershed includes East Park, Stony Gorge, and Black Butte reservoirs. Lower Stony Creek is the 25-mile-long stretch of the creek from Black Butte Dam to the creek's confluence with the Sacramento River.

Monthly flows in Stony Creek below Black Butte Dam (USGS 11388000) are available from July 1955 through September 1990. Reservoir releases from Black Butte Dam to Stony Creek and Dam releases to the Orland Project's South Canal are available for USACE beginning in October 1963. DWR (1982) report published flows from January 1951 through June 1955.

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[19] The factor of 1.05 is from old DWR planning records. The source is unknown.

For the CalSim 3.0 hydrology, flows in Stony Creek at the Black Butte Dam site before October 1934 were estimated as the sum of observed flows for Stony Creek near Orland (USGS 11387500) and 1.49 times the flow in North Fork Stony Creek near Newville (USGS 11387800). From October 1934 through December 1950, flows were estimated by correlation with natural inflows to East Park Reservoir and Stony Gorge Reservoir. Beginning in January 1951, flows are taken directly from DWR, USGS and USACE records.

Cache Creek at Yolo

Cache Creek originates at Clear Lake and flows east to discharge into the Yolo Bypass upstream from the Woodland gauge (USGS 11453000). Upper Cache Creek is the portion of the watershed located upstream from the Capay Diversion Dam, which was built in 1914 to facilitate agricultural diversions. The upper watershed includes both Clear Lake and Indian Valley Reservoir. The lower watershed consists of the 30-mile reach between Capay Diversion Dam and the Yolo Bypass. Under natural conditions, Cache Creek is an ephemeral stream.

Cache Creek at Yolo (model node CCH012) represents outflows from Cache Creek to the Cache Creek stilling basin and the Yolo Bypass. Flows primarily consist of flood releases from Clear Lake and Indian Valley Reservoir, supplemented by unregulated runoff from the Capay Valley. Yolo County Flood Control and Water Conservation District (FC&WCD) diverts water for agricultural purposes upstream from the Woodland gauge at the Capay Diversion Dam.

Monthly flow records for Cache Creek at Yolo are available from January 1903 onward (USGS 11452500). The gauge is located 35 feet upstream from the Interstate 5 Road Bridge, approximately 7.3 miles downstream from Moore Dam, and 0.5 miles south of the town of Yolo. Typically, the creek is dry from June through October.

The historical flow record for the CalSim 3.0 hydrology is directly from USGS records.

Yolo Bypass near Woodland

The Yolo Bypass was completed in 1924 as part of the Sacramento River Flood Control Project, providing flood relief for the City of Sacramento. It stretches 41 miles from Fremont Weir to Cache Slough. The bypass is bounded by two levees set 1.3 to 3.0 miles apart, except for an 8-mile-long reach that has no western boundary but is defined by ground at a higher elevation to the west. In addition to the Fremont Weir, the Yolo Bypass receives inflow from the Sacramento Weir, Knights Landing Ridge Cut, Cache Creek, Willow Slough, and Putah Creek. The flood capacity of the bypass increases from approximately 377,000 CFS at Freemont Weir to 490,000 CFS south of Putah Creek.

At the low stage, surface water flows across the bypass from west to east into a side drain that runs parallel to the eastern levee for the entire length of the bypass. North of Interstate 80 (I-80), this artificial channel is called the “Tule Canal”; south of I-80 it is referred to as the “Toe Drain.” The Toe Drain enters Prospect Slough near Liberty Island, a few miles north of where the slough merges with Cache Slough. During the summer and fall, flows are dominated by agricultural return flows, augmented by discharges from the Woodland and Davis wastewater treatment plants. The Lisbon Weir located near MP 21 at a prominent bend in the east levee, controls tidal flows in and out of the bypass. The weir crest elevation is set at approximately the midpoint of the tidal range, providing a pool elevation for agricultural pumps, and allowing this pool to be replenished at high tide.

Spills over the Fremont and Sacramento weirs are gauged and daily flow data are available from DWR. The only gauge within the Yolo Bypass upstream from tidal influence is the Woodland gauge (USGS 11453000). The gauge is located 300 feet upstream from the Sacramento-Woodland Railroad Bridge, and approximately 6 miles upstream from the Sacramento Weir and Bypass. The majority of flow measured by the gauge is from Cache Creek and Knights Landing Ridge Cut, augmented by any flood water that spills over the Fremont Weir. During the summer months, flow is primarily derived from irrigation return flows. Starting in October 1939, flow was measured by a high-flow gauge in the main channel, supplemented by a low-flow gauge located in the toe drain. The low-flow gauge was removed in September 1977. Since that date, flows of less than 1,000 CFS are not recorded.

For the CalSim 3.0 hydrology, flows for the Yolo Bypass near Woodland (model node YBP032) are from the following sources. From October 1921 through September 1939, estimates of historical monthly flows are from Table 53 of the *1957 Joint Hydrology Study* (DWR, 1958). Subsequently, historical monthly flows are generally from USGS records. However, beginning in October 1977, there are many months of no data when flows were less than 1,000 CFS. Estimates of low flows were made based on a flow balance for water years 1947 through 2015. Low flows were calculated as the sum of flows in Cache Creek at Yolo (USGS 11452500) and Knights Landing Ridge Cut (estimated as described below) and Fremont Weir spills (USGS 11391021), less estimated agricultural diversions from the Knights Landing Ridge Cut.

Putah Creek near Davis

The Putah Creek watershed is divided into upper and lower watersheds by Monticello Dam, which forms Lake Berryessa. The lower watershed includes the 30-mile-long lower Putah Creek corridor contained within a relatively narrow 110-square-mile contributing drainage area. At Putah Diversion Dam, located approximately 6 miles downstream from Monticello Dam, Solano County WA diverts water from Putah Creek into the Putah South Canal for agricultural and M&I purposes. Further downstream, the South Fork of Putah Creek, an artificial channel constructed over a period of decades beginning in the 1870s, departs from the natural creek channel about 1 mile upstream from I-80 and flows directly to the Yolo Bypass. The original channel (North Fork) was abandoned, and for practical purposes, the South Fork is the channel of Putah Creek.

Flow in lower Putah Creek is measured at Putah Creek near Winters (USGS 11454000) and at the Putah Diversion Dam (spills over the dam are recorded by Solano ID). Observed flow data for the South Fork Putah Creek near Davis (model node PTH007) are available from October 1948 to December 1962 (USGS 11455000). Additional data are available from DWR gauges from October 1962 to September 1986 for Putah Creek above Davis (A09145) and Putah Creek near Davis (A09115). These records are incomplete. Beginning in August 2008, flows are measured by Solano County WA at the I-80 Bridge.

For CalSim 3.0, flows for Putah Creek near Davis before October 1948 are estimated as 0.97 times the historical flows at Putah Creek near Winters (USGS 11454000). The factor was determined through correlation and the line of linear regression has an r^2 value greater than 0.99. Beginning in 1986, flows are calculated as 0.90 times the flow passed the Putah Creek Diversion

Dam. This factor also was determined through linear regression and the resulting relationship has an r^2 value of 0.99. Beginning in August 2008, flows are as measured at the I-80 Bridge.

Fremont Weir

The Fremont Weir (model node YBP037) is not a CalSim 3.0 control point. However, weir spills from the Sacramento River to the Yolo Bypass are important in determining the closure term for both the Sacramento River at Verona and the Yolo Bypass near Woodland. From October 1921 through December 1946, data are from Table 51 of the *1957 Joint Hydrology Study*. From January 1947 through September 1975 data are from the gauge Fremont Weir spill to Yolo Bypass near Verona (USGS 11391021). Beginning in October 1975, data are from DWR Division of Flood Management.

Knights Landing Ridge Cut

The Knights Landing Ridge Cut is not a CalSim 3.0 control point. However, flows through this channel are important in determining the closure term for both the Colusa Basin Drain at the Knights Landing Outfall Gates and the Yolo Bypass near Woodland. Historical flow data for the channel are limited. A partial flow record is available from April 1933 through September 1956. Summertime flows (April to October) were published in Bulletin 23 from 1933 through 1956. Year round flows were published from 1939 to 1955, except no data are available for calendar years 1944 and 1945.

Flows through the Knights Landing Ridge Cut were initially estimated from a flow balance using gauge data for the Yolo Bypass near Woodland, Cache Creek at Yolo, Fremont Weir spills, and diversions from the Ridge Cut. For the irrigation months (April through September), estimates from the flow balance were increased, if necessary, to achieve a minimum monthly base of 5.0, 5.0, 3.0, 3.0, 3.0, and 2.0 TAF. During high-flow months, the flow balance often resulted in unreliable estimates, probably due to difficulty in accurately measuring high flows in the Yolo Bypass. A second method for estimating flows was adopted to screen the initial flow estimates. Colusa Basin Drain flows upstream from the Knights Landing Ridge Cut (calculated as the sum of flows through the outfall gates and through the ridge cut) were correlated with gauged flows in the Colusa Basin Drain at Highway 20 (A02976). Two linear relationships were derived, one for the irrigation months and one for the non-irrigation months, as follows:

For April – September:

$$Q_{ColusaBasinDrainTotal} = 1.17 * Q_{ColusaBasinDrainatHighway20} - 8.05\ (\mathit{TAF/month}) \qquad \text{Eqn. 16-1}$$

For October – March:

$$Q_{ColusaBasinDrainTotal} = 1.28 * Q_{ColusaBasinDrainatHighway20} - 0.90\ (\mathit{TAF/month}) \qquad \text{Eqn. 16-2}$$

The r^2 values for the two regression equations are 0.83 and 0.90. Flows through the Knights Landing Ridge Cut were subsequently estimated by subtracting flows for the Colusa Basin Drain at Knights Landing from the derived total flow for the drain. The confidence limits for the linear relationships were assumed to be 20 percent. The initial flow estimates for the Knights Landing Ridge Cut were limited to a maximum of 1.2 times the flow estimate obtained through correlation, and a minimum of 0.8 times the flow estimate obtained through correlation.

Bank Overflow

Near the City of Red Bluff, the Sacramento River flows out of a narrow canyon at the southern end of the Redding basin, onto the broad alluvial floodplain of the Sacramento Valley. Historically south of the town of Chico, the Sacramento River and its major tributaries overtopped their banks during periods of high runoff, spilling water into the Butte, Sutter, American, and Sacramento basins to the east and into the Colusa and Yolo basins to the west. Flows in the Sacramento River are now controlled by the Sacramento River Flood Control Project, constructed by USACE. The levee system on the west bank of the Sacramento River stretches from the Stony Creek watershed to Knights Landing, Additionally, a back levee along the east bank of the Colusa Basin Drain stretches from the town of Knights Landing to high ground near the town of Colusa. On the left bank of the Sacramento River, levees begin near the town of Ord Ferry.

Before the completion of Shasta Dam in 1945, it is believed that a portion of bank overflow did not return to the river system downstream, but formed natural wetlands. This water was gradually dissipated through evaporation and seepage. DWR's planning office (Roos, 2011) identified an apparent change in runoff characteristics for Sacramento Valley flows entering the Delta after 1945. DWR estimated that approximately 4 percent of the Sacramento Valley outflow was "lost" as a result of bank overflow before this date. Hydrology development for CalSim II (and its predecessors) has used this value when computing historical flow balances. To provide consistency with previous work, this assumption was adopted for CalSim 3.0. The magnitude of bank overflows that subsequently do not reach the Delta are summarized in Table 16-3.

Table 16-3. Overbank Flow Not Reaching the Delta

Closure Term	Associated Depletion Study Area[1]		Loss Factor[2]	Average Annual Overbank Flow (TAF)[3]
	ID	Description		
CT_Colusa	12	Sacramento Valley Westside above Colusa Basin Drain	0.279	188
CT_WilkinsSl	15	Sacramento River at Knights Landing	0.111	75
CT_Davis	65	Yolo Bypass and westside minor streams	0.146	99
CT_Nicolaus	69	Lower Feather River to mouth	0.199	134
CT_Freeport	70	Lower Sacramento River to Delta	0.265	179
Total			1.000	675

Notes:
[1] Depletion Study Areas are used for regional water balances in CalSim II.
[2] The loss factor is a fraction of 4 percent of the Sacramento Valley outflow.
[3] Water years 1922 through 1945.
Key:
Delta = Sacramento-San Joaquin Delta
ID = identification number
TAF = thousand acre-feet

Closure Term Summaries

The following sections briefly describe each closure term. Figures presenting average monthly values of the closure terms and their various flow components in tabular and graphical form follow these sections. Components of the flow balances are categorized as follows:

- **Inflows**: flows at upstream control locations.
- **Groundwater inflows**: accretions to the stream system from the groundwater aquifer.
- **Return flows**: combined irrigation return flows and treated wastewater return flows.
- **Rim inflows:** flows from one or more of the 60 rim watersheds described in Chapter 5.
- **Runoff**: surface runoff from precipitation as simulated by CalSim Hydro for the historical land use.
- **Imports**: canal imports from stream systems that are part of other flow balances.
- **Storage gain**: increase in storage in surface water reservoirs.
- **Evaporation**: open water evaporation from lakes and reservoirs.
- **Outflows:** flows at the downstream control location(s).
- **Diversions**: stream diversions for agricultural, municipal, and environmental (wetlands) purposes.
- **Exports**: canal exports to stream systems that are part of other flow balances.

Sacramento Valley Closure Terms

No closure terms have been developed for Sacramento River at Shasta Dam or Stony Creek below Black Butte Dam. Upstream rim inflows were developed using the downstream gauge data so that the resulting closure terms would be zero. Additionally, local inflows to Lake Oroville and to Lake Folsom have partly been developed using downstream gauge data; therefore, these closure terms are small.

Sacramento River above Bend Bridge

The closure term for the Sacramento River above Bend Bridge resolves discrepancies between derived and observed outflows from the Redding basin. The drainage area for the closure term represents the Sacramento River watershed from Shasta Dam to 8 miles northeast of the City of Red Bluff at the site of the USGS gauge (11377100). The most significant tributaries in this drainage area are Clear, Cottonwood, Cow, Battle, and Bear creeks. Figure 16-4 shows average monthly values for the various components of the historical flow balance. The dominant components in the flow balance are inflows (to Shasta Dam), storage regulation (Shasta, Whiskeytown, Keswick), and outflows (at the Bend Bridge gauge). Rim inflows (not including inflows to Lake Shasta), and to a lesser extent surface runoff, are significant components during the winter and spring months. Because rim inflows are significant, closure terms are added to CalSim 3.0 in all months.

Sacramento River at Butte City

The closure term for the Sacramento River at Butte City (USGS 11377100) resolves discrepancies between calculated and observed historical flows for the Sacramento River at a location downstream from left and right bank tributaries.[20] Figure 16-5 shows average monthly values for the various components of the historical flow balance. Inflows (Sacramento River above Bend Bridge) and outflows dominate the flow balance. Outflows include spills to the Butte basin over the M&T, 3Bs, and Goose Lake flood relief structures. There are significant rim inflows in winter and spring, and significant agricultural diversions during the irrigation season. The largest tributaries include Elder, Thomes, Stony, Paynes, Antelope, Mill, Deer, and Big Chico creeks. The three Stony Creek reservoirs (East Park, Stony Gorge, and Black Butte) provide the only significant storage regulation. Because rim inflows are significant, closure terms are added to CalSim 3.0 in all months.

Sacramento River below Wilkins Slough

The closure term for the Sacramento River below Wilkins Slough resolves discrepancies between calculated and observed historical flows for the Sacramento River in the vicinity of the Navigation Control Point (NCP). Figure 16-6 shows average monthly values for the various components of the historical flow balance. The drainage area associated with the closure term is a relatively narrow riparian corridor between the gauge Sacramento River at Butte City (USGS 11389000) and the gauge Sacramento River below Wilkins Slough, near Grimes (USGS 11391000). The flow balance is dominated by the flows at these two gauges, and by flood flows over the Moulton, Colusa, and Tisdale weirs. During the irrigation season, there are significant diversions for agricultural purposes. Imports represent flows from Butte Creek to the Sacramento River through the Butte Slough Outfall Gates. Because rim inflows are not part of the flow balance, closure terms are added to CalSim 3.0 for the months of November through March, only.

Colusa Basin Drain at Knights Landing Outfall Gates

The closure term for the Colusa Basin Drain at Knights Landing Outfall Gates resolves discrepancies between calculated and observed historical outflows from the Colusa basin. Figure 16-7 shows average monthly values for the various components of the historical flow balance. There are no inflows from upstream control locations or from rim watersheds. However, there is significant surface runoff during the winter and spring months, and significant groundwater inflow to the drain. Outflows from the basin are the sum of flows through the Knights Landing Outfall Gates and through the Knights Landing Ridge Cut. The flow balance is complicated by significant agricultural diversions and irrigation return flows during the irrigation season, for which no reliable data were found.

Because rim inflows are not part of the flow balance, closure terms are added to CalSim 3.0 for the months of November through March, only.

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[20] There are no tributary inflows to the Sacramento River below Butte City, except the Sacramento Slough, Feather River, and American River.

Sacramento River at Verona

The closure term for the Sacramento River at Verona (USGS 11425500) resolves discrepancies between calculated and observed historical flows for the Sacramento River below its confluence with the Feather River. Figure 16-8 shows average monthly values for the various components of the historical flow balance. The drainage area associated with this closure term is relatively small, and the primary terms in the flow balance are inflows from upstream control points (Colusa Basin Drain at Knights Landing Outfall Gates, Sacramento River below Wilkins Slough, Feather River at Nicolaus, and Sacramento Slough near Karnak), outflow at the Verona gauge, and flood spills over the Fremont Weir. The Natomas Cross Canal contributes to flow measured at the Verona gauge. Natomas Cross Canal flows are driven by imports from the Bear River and American River watersheds, surface runoff in the winter months, and irrigation return flows during the summer months. Groundwater inflows are small.

Because rim inflows are not part of the flow balance, closure terms are added to CalSim 3.0 for the months of November through March, only.

Sacramento River at Freeport

The closure term for the Sacramento River at Freeport (USGS 11447650) resolves discrepancies between calculated and observed historical flows for the Sacramento River below its confluence with the American River before entering the Delta. Figure 16-9 shows average monthly values for the various components of the historical flow balance. The flow balance is almost entirely a balance between inflows from upstream control locations (Sacramento River at Verona, American River at Fair Oaks), flood spills over the Sacramento Weir to the Yolo Bypass, and outflows at the Freeport gauge.

Because rim inflows are not part of the flow balance, closure terms are added to CalSim 3.0 for the months of November through March, only.

Feather River at Oroville

The closure term for the upper Feather River resolves discrepancies between calculated and measured historical flows for the Feather at Oroville.[21] Figure 16-10 shows average monthly values for the various components of the historical flow balance. Rim inflows include those to the West Branch, North, Middle and South forks Feather River). The outflow is equivalent to the inflow to Lake Oroville. Local inflows to Lake Oroville have partly been developed using downstream gauge data, so closure terms are generally small. The closure terms are added to CalSim 3.0 in all months of the simulation.

Feather River near Nicolaus

The closure term for the lower Feather River resolves discrepancies between calculated and measured historical flows for the Feather River near Nicolaus (USGS 11425000). Figure 16-11 shows average monthly values for the various components of the historical flow balance. The major flow components are inflows from upstream control locations (Feather River at Oroville, Yuba River at Smartville, and Bear River near Wheatland), rim inflows (French Dry Creek, Dry

[21] Beginning in October 1967, closure terms are based on inflows to Lake Oroville as determined by DWR's Operations Control Office (OCO).

and Hutchinson creeks, Honcut Creek), and storage regulation (Lake Oroville, Thermalito Afterbay, Merle Collins Reservoir). There are significant agricultural diversions during the irrigation season, both directly from the river and from the Thermalito Afterbay.

Estimated flows for the Feather River near Nicolaus beginning in October 1983 are considered approximate. The magnitude of rim inflows also is relatively small. Therefore, it was decided to add closure terms to CalSim 3.0 for the months of November through March, only.

Sacramento Slough near Karnak

The closure term for the Sutter Bypass resolves discrepancies between calculated and measured historical flows for the Sacramento Slough near Karnak (DWR A02972). Figure 16-12 shows average monthly values for the various components of the historical flow balance. The drainage area associated with the closure term is relatively large, including the majority of the Butte Creek watershed and the Butte and Sutter basins.

The major inflows for this closure term include Sacramento River spills to the Butte and Sutter basins (at the 3Bs, M&T, and Goose Lake overflow structures, and Moulton, Colusa, and Tisdale weirs) and rim inflows (Butte Creek, Little Chico Creek, and Little Dry Creek).

Rim inflows for the upper Butte Creek watershed are considered reliable. Rim inflows from Little Chico and Little Dry creeks are relatively small. In the summer months, there is considerable uncertainty in estimating both irrigation diversions and return flows. Therefore, closure terms are added to CalSim 3.0 for the months of November through March, only.

Yuba River at Smartville

The closure term for the Yuba River resolves discrepancies between calculated and measured historical flows for the Yuba River at Smartville (USGS 11419000, discontinued). Figure 16-13 shows average monthly values for the various components of the historical flow balance. In all months, the flow components are dominated by rim inflows, storage regulation, and outflow. Surface runoff and groundwater inflow are not parts of the flow balance at this location.

Rim inflows are an important part of the flow balance so that closure terms are added to CalSim 3.0 in all months.

Bear River near Wheatland

The closure term for the Bear River resolves discrepancies between calculated and measured historical flows for the Bear River near Wheatland (USGS 11425500). Figure 16-14 shows average monthly values for the various components of the historical flow balance. In all months, the flow components are dominated by rim inflows (including imports from Lake Spaulding via the Drum Canal), diversions (for hydropower, agricultural, and M&I purposes), and storage regulation. Surface runoff is a minor component because of the small associated drainage area. In the summer months, there is some return flow from irrigation.

Rim inflows are an important part of the flow balance, therefore closure terms are added to CalSim 3.0 in all months.

American River at Fair Oaks

The closure term for the American River resolves discrepancies between calculated and measured historical flows for the American River at Fair Oaks (USGS 11446500). Figure 16-15 shows average monthly values for the various components of the historical flow balance. In all months the flow balance is dominated by rim inflows, storage regulation, and outflow. Imports from the Bear River watershed and diversions for M&I purposes are also significant.

Rim inflows are an important part of the flow balance so that closure terms are added to CalSim 3.0 in all months.

Cache Creek at Yolo

The closure term for Cache Creek resolves discrepancies between calculated and measured historical flows for Cache Creek at Yolo (USGS 11453000). Figure 16-16 shows average monthly values for the various components of the historical flow balance. In the winter months, rim inflows, surface runoff, groundwater inflow, increases in storage, and outflows (at the Yolo gauge) are all important components in the flow balance. In the summer months, rim inflows are less important, and the flow balance is dominated by releases from storage, reservoir/lake evaporation, and diversions (from Cache Creek at the Capay Diversion Dam).

Rim inflows are an important part of the flow balance so that closure terms are added in CalSim 3.0 in all months.

Yolo Bypass near Woodland

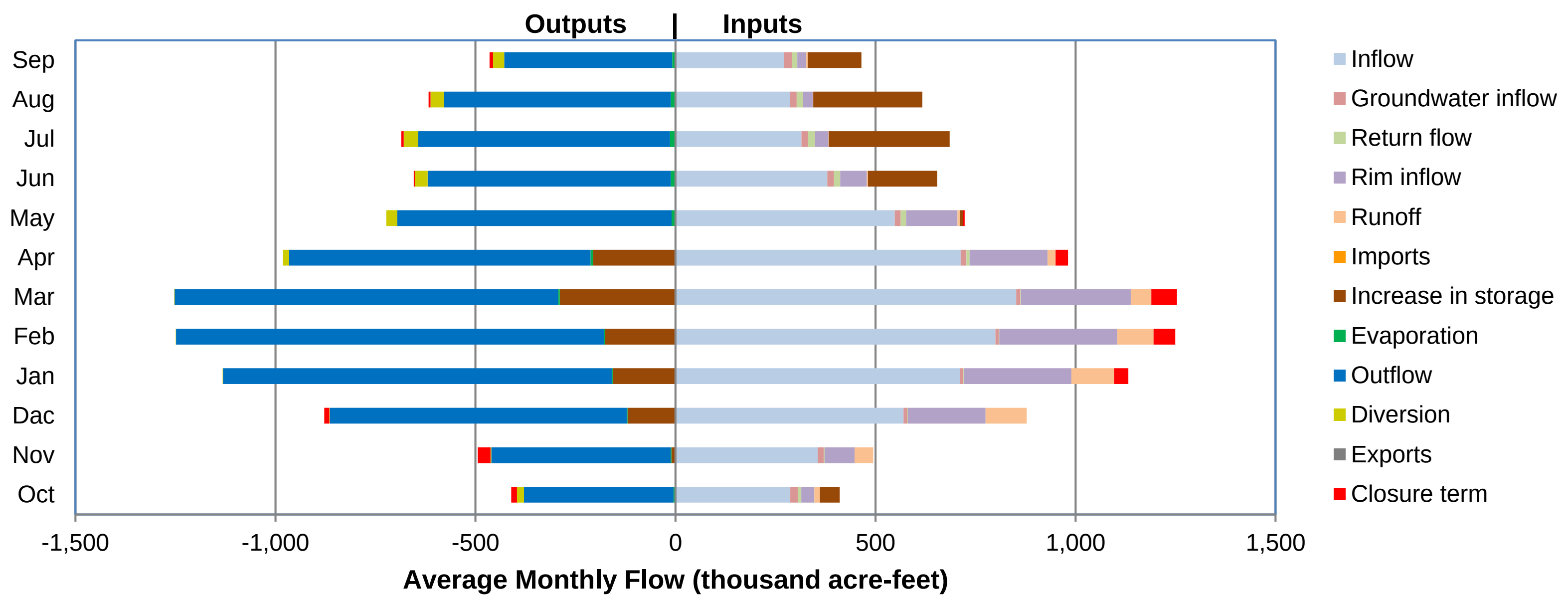
The closure term for Yolo Bypass resolves discrepancies between calculated and measured historical flows for the Yolo Bypass near Woodland (USGS 11453000). Figure 16-17 shows average monthly values for the various components of the historical flow balance. For the months December through April, the flow balance is dominated by inflows from upstream closure terms and outflows from the bypass. Inflows include Fremont Weir spills, Cache Creek at Yolo, and Knights Landing Ridge Cut (which is ungauged). Surface runoff is a minor component because of the small associated drainage area. Average monthly values presented in the figure may be misleading because of large discrepancies in observed gauge data during a few extreme events. From May through November, components of the flow balance are relatively small.

Because rim inflows are not part of the flow balance, closure terms are added to CalSim 3.0 for the months of November through March, only.

Putah Creek near Davis

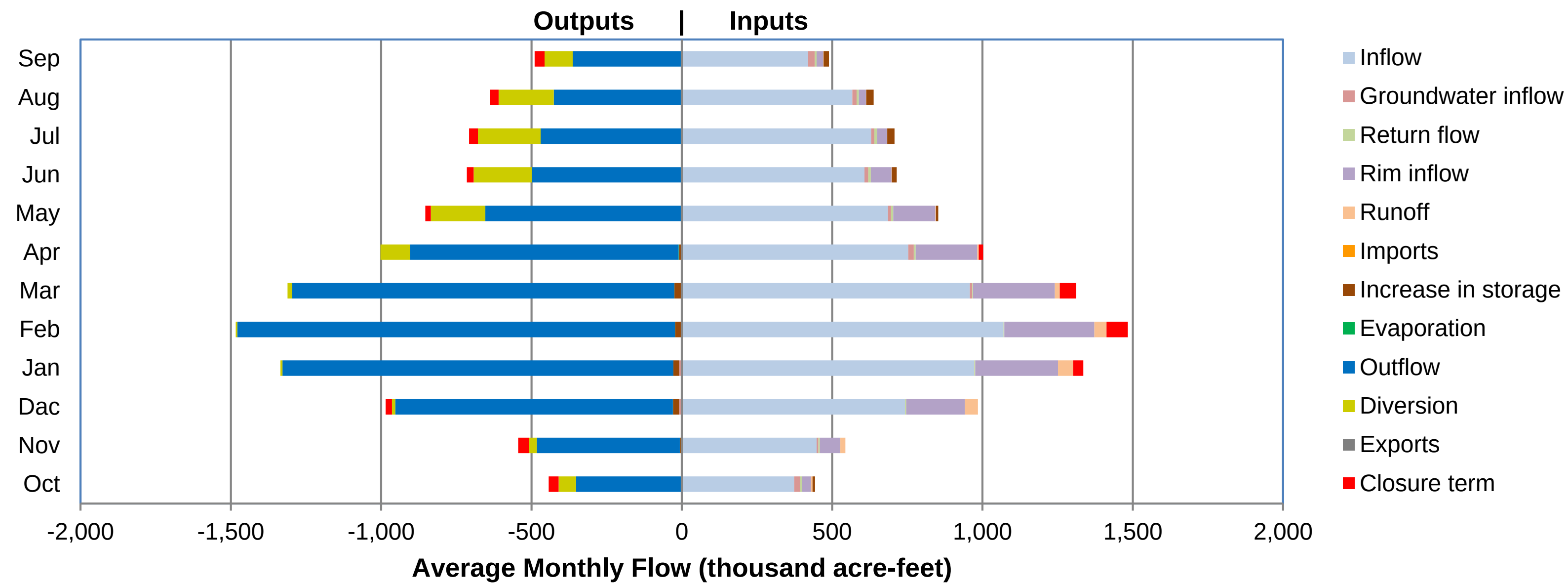
The closure term for Putah Creek resolves discrepancies between calculated and measured historical flows at the site of the former gauge Putah Creek near Davis (USGS 11455000, discontinued). Figure 16-18 shows average monthly values for the various components of the historical flow balance. In the winter months, the largest flow components are rim inflows (to Lake Berryessa), increases in storage, and outflows (from Putah Creek to the Yolo Bypass). Surface runoff is a relatively minor component because of the small drainage area. In the summer months, the largest flow components are releases from storage (in Lake Berryessa) and diversions (from Putah Creek to the Putah South Canal).

Gauge data used to construct the rim inflows are considered more reliable than the estimated flows for Putah Creek near Davis. Therefore, it was decided to add the closure term to CalSim 3.0 for the months of November through March, only.



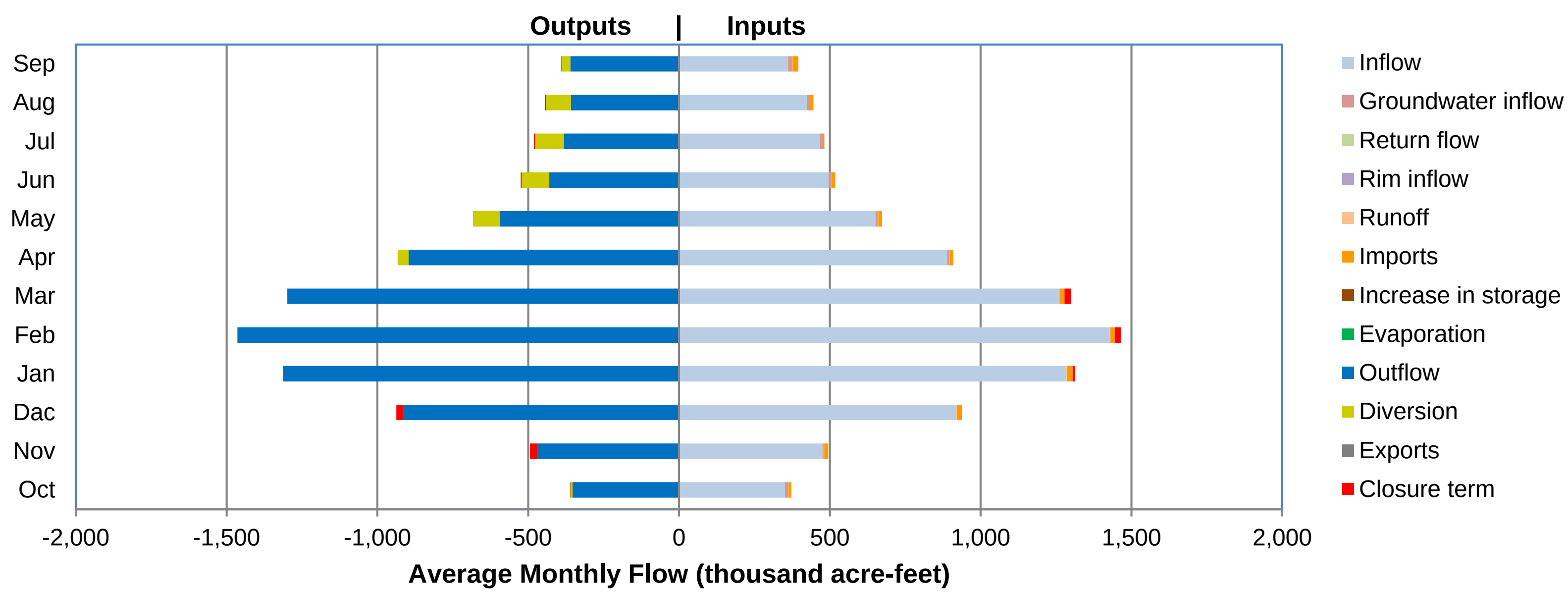
Flow Component	Average Monthly Flow (thousand acre-feet)												
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
Inflow	287	356	570	712	800	852	713	548	379	315	286	272	6,088
Groundwater Inflow	19	15	9	8	8	11	14	15	17	17	17	19	169
Return Flow	9	2	1	1	1	1	8	13	15	17	16	14	99
Rim Inflow	33	75	194	269	295	274	195	128	67	34	25	23	1,610
Runoff	14	47	103	107	91	52	20	7	3	1	1	4	447
Imports	0	0	0	0	0	0	0	0	0	0	0	0	0
Increase In Storage	-50	10	120	157	176	290	206	-7	-173	-302	-273	-134	20
Evaporation	5	2	2	2	2	4	6	10	12	14	12	8	78
Outflow	374	448	742	973	1,070	959	753	686	608	630	567	420	8,230
Diversion	17	2	1	1	1	1	15	27	32	36	33	28	195
Exports	0	0	0	0	0	0	0	0	0	0	0	0	0
Closure Term	-15	-32	-13	35	54	64	31	5	-3	-6	-5	-9	109

Figure 16-4. Closure Term Flow Components, Sacramento River above Bend Bridge



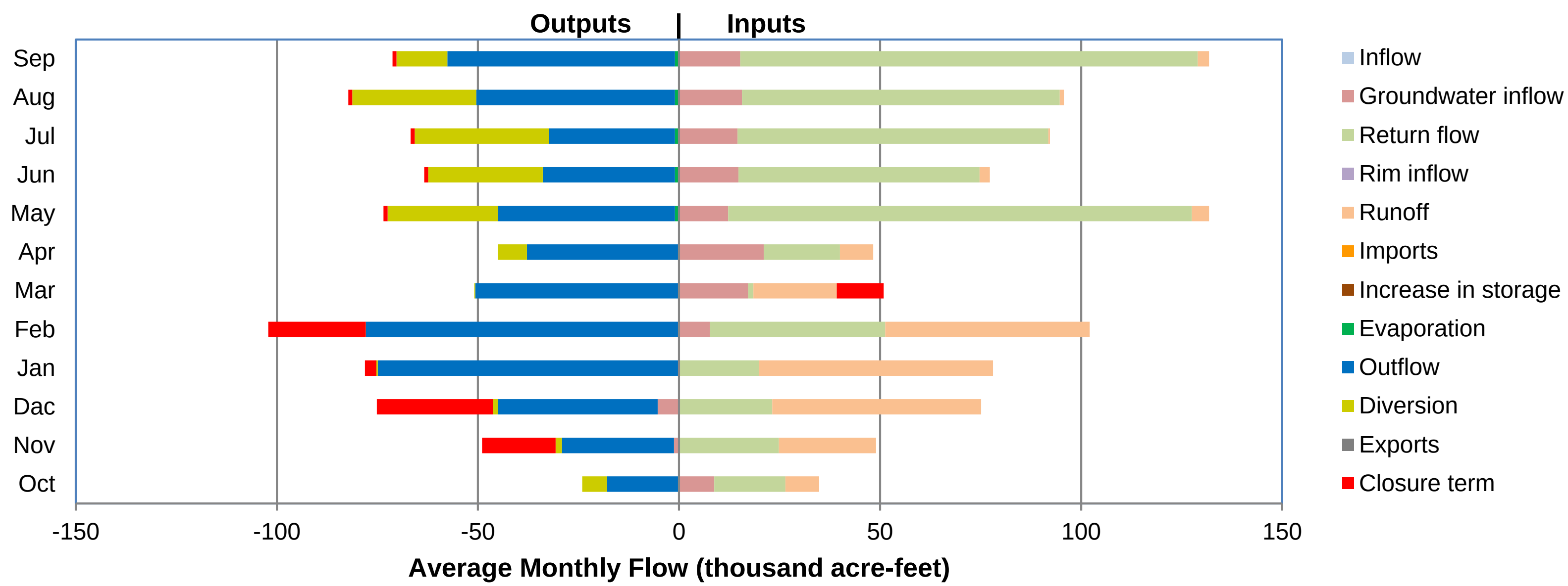
Flow Component	Average Monthly Flow (thousand acre-feet)												
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
Inflow	374	448	743	973	1,070	958	753	686	608	630	567	420	8,230
Groundwater Inflow	20	6	-9	-9	-2	8	18	10	12	11	14	22	101
Return Flow	6	5	4	3	3	3	7	7	8	9	7	6	67
Rim Inflow	30	68	195	276	299	272	204	141	69	34	24	22	1,635
Runoff	5	17	43	50	41	17	5	2	1	1	1	1	183
Imports	0	0	0	0	0	0	0	0	0	0	0	0	0
Increase In Storage	-8	6	20	19	20	24	9	-7	-16	-24	-25	-18	1
Evaporation	1	0	0	0	0	1	1	2	3	3	2	1	16
Outflow	351	476	923	1,300	1,456	1,271	893	651	496	467	424	362	9,069
Diversion	58	26	11	7	5	16	98	182	193	209	183	93	1,082
Exports	0	0	0	0	0	0	0	0	0	0	0	0	0
Closure Term	-33	-36	-21	33	71	54	15	-18	-22	-29	-29	-33	-48

Figure 16-5. Closure Term Flow Components, Sacramento River at Butte City



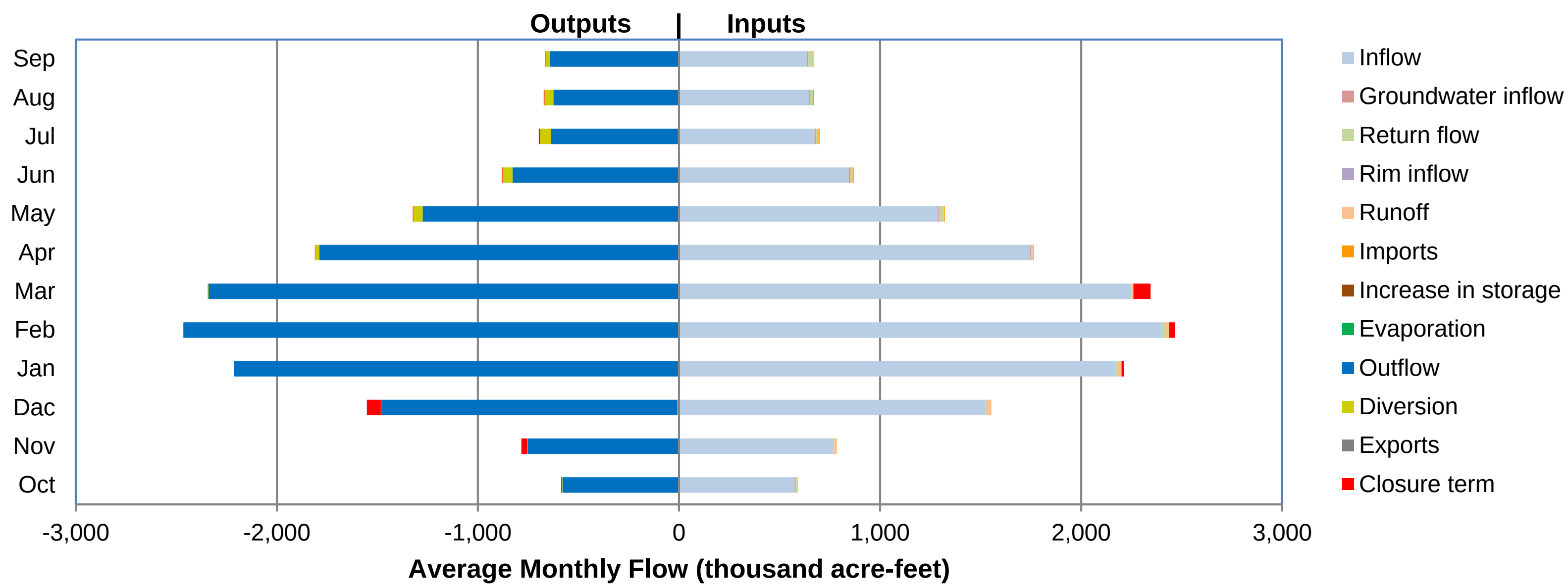
Flow Component	Average Monthly Flow (thousand acre-feet)												
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
Inflow	351	476	918	1,284	1,427	1,259	889	651	496	467	424	362	9,003
Groundwater Inflow	11	4	-3	-2	1	3	8	8	10	9	11	13	73
Return Flow	0	1	1	1	1	0	0	1	0	0	1	2	8
Rim Inflow	0	0	0	0	0	0	0	0	0	0	0	0	0
Runoff	1	1	2	2	2	1	0	0	0	0	0	0	10
Imports	10	13	16	19	14	15	12	13	11	6	11	20	159
Increase In Storage	0	0	0	0	0	0	0	0	0	0	0	0	0
Evaporation	1	0	0	0	0	0	0	1	3	3	3	2	13
Outflow	352	469	913	1,311	1,464	1,299	897	593	427	379	355	358	8,817
Diversion	8	0	0	0	0	1	36	87	91	96	83	28	432
Exports	0	0	0	0	0	0	0	0	0	0	0	0	0
Closure Term	-1	-25	-22	7	20	22	0	-1	-3	-3	-3	-2	-11

Figure 16-6. Closure Term Flow Components, Sacramento River below Wilkins Slough



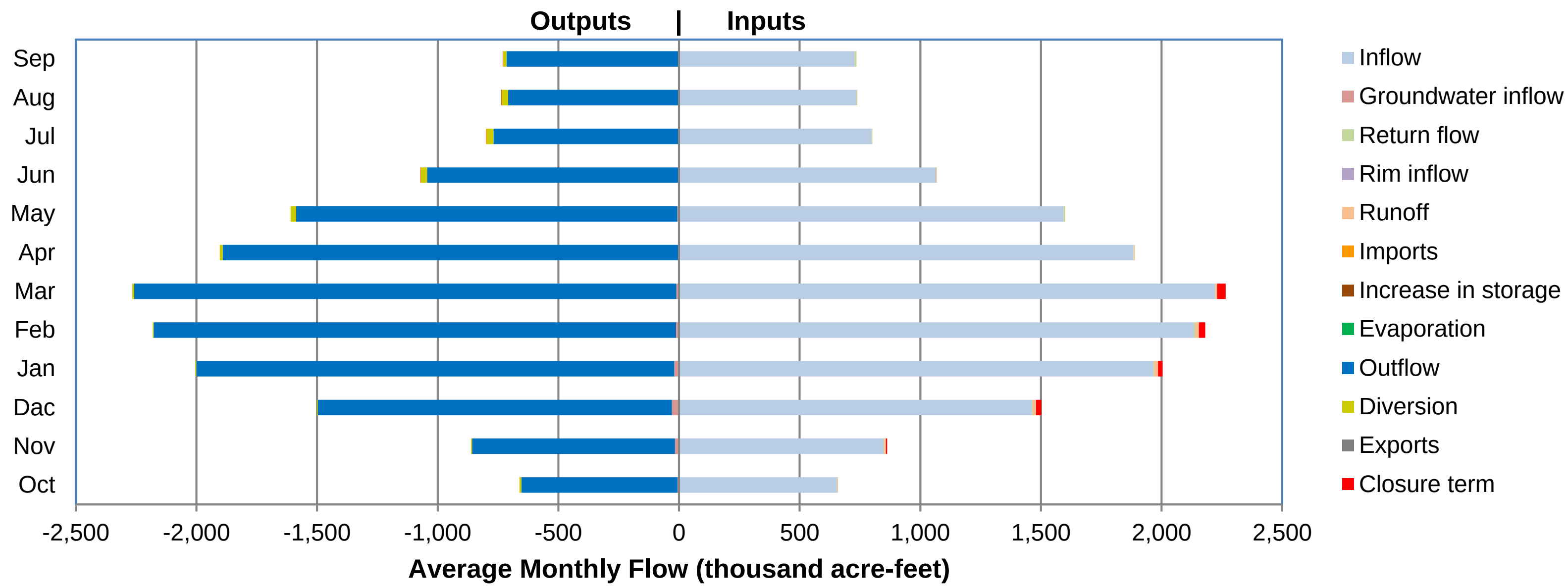
Flow Component	Average Monthly Flow (thousand acre-feet)												
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
Inflow	0	0	0	0	0	0	0	0	0	0	0	0	0
Groundwater Inflow	9	-1	-5	0	8	17	21	12	15	15	16	15	121
Return Flow	18	25	23	20	44	1	19	115	60	77	79	114	594
Rim Inflow	0	0	0	0	0	0	0	0	0	0	0	0	0
Runoff	8	24	52	58	51	21	8	4	3	0	1	3	234
Imports	0	0	0	0	0	0	0	0	0	0	0	0	0
Increase In Storage	0	0	0	0	0	0	0	0	0	0	0	0	0
Evaporation	0	0	0	0	0	0	0	1	1	1	1	1	5
Outflow	18	28	40	75	78	51	38	44	33	31	49	57	541
Diversion	6	2	1	0	0	0	7	27	28	33	31	13	150
Exports	0	0	0	0	0	0	0	0	0	0	0	0	0
Closure Term	0	-18	-29	-3	-24	12	0	-1	-1	-1	-1	-1	-68

Figure 16-7. Closure Term Flow Components, Colusa Basin Drain at Outfall Gates



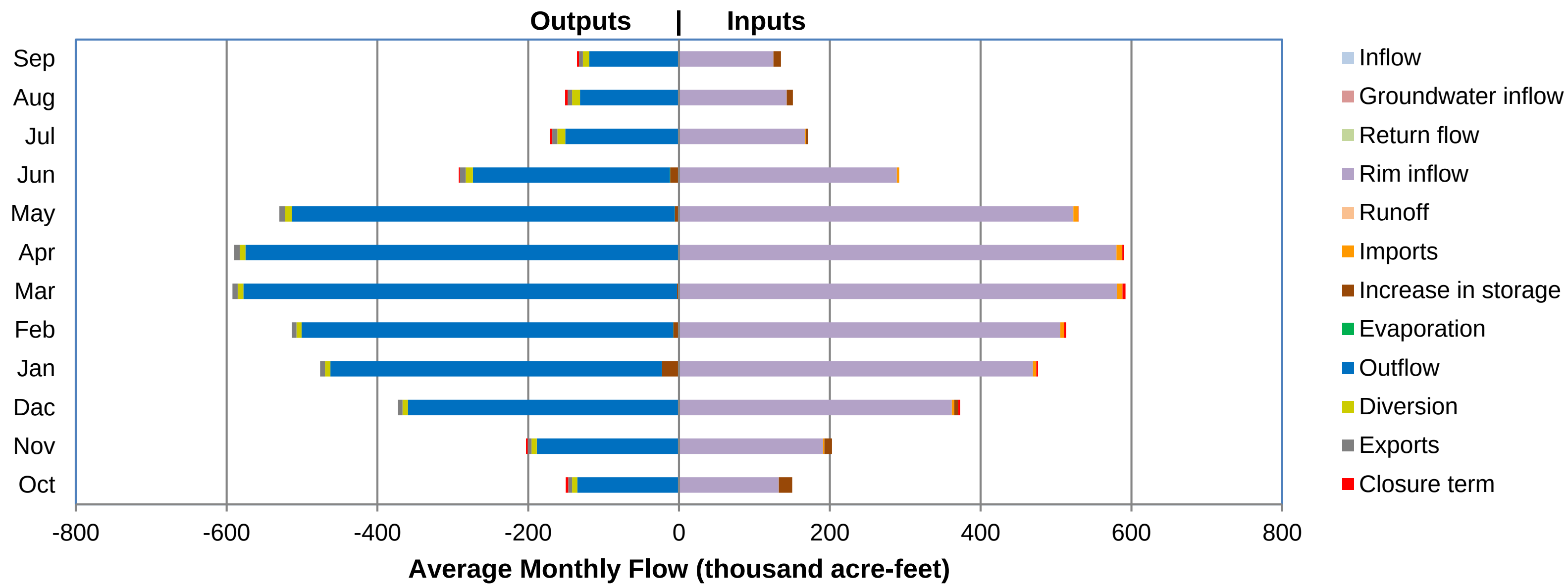
Flow Component	Average Monthly Flow (thousand acre-feet)												
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
Inflow	575	765	1,523	2,172	2,405	2,248	1,747	1,289	844	674	646	636	15,524
Groundwater Inflow	5	0	-9	-4	-2	1	5	5	9	7	7	8	31
Return Flow	5	7	7	6	12	1	6	22	10	11	12	25	125
Rim Inflow	0	0	0	0	0	0	0	0	0	0	0	0	0
Runoff	4	12	22	23	21	10	5	2	1	0	0	1	101
Imports	1	0	0	0	0	0	3	4	5	6	5	3	29
Increase In Storage	0	0	0	0	0	0	0	0	0	0	0	0	0
Evaporation	2	0	0	0	0	0	1	2	4	5	4	3	21
Outflow	577	752	1,473	2,208	2,463	2,340	1,788	1,273	824	632	620	640	15,591
Diversion	4	2	1	2	3	5	21	47	50	55	44	19	252
Exports	0	0	0	0	0	0	0	0	0	0	0	0	0
Closure Term	-2	-30	-69	14	30	85	-1	-2	-4	-5	-4	-3	8

Figure 16-8. Closure Term Flow Components, Sacramento River at Verona



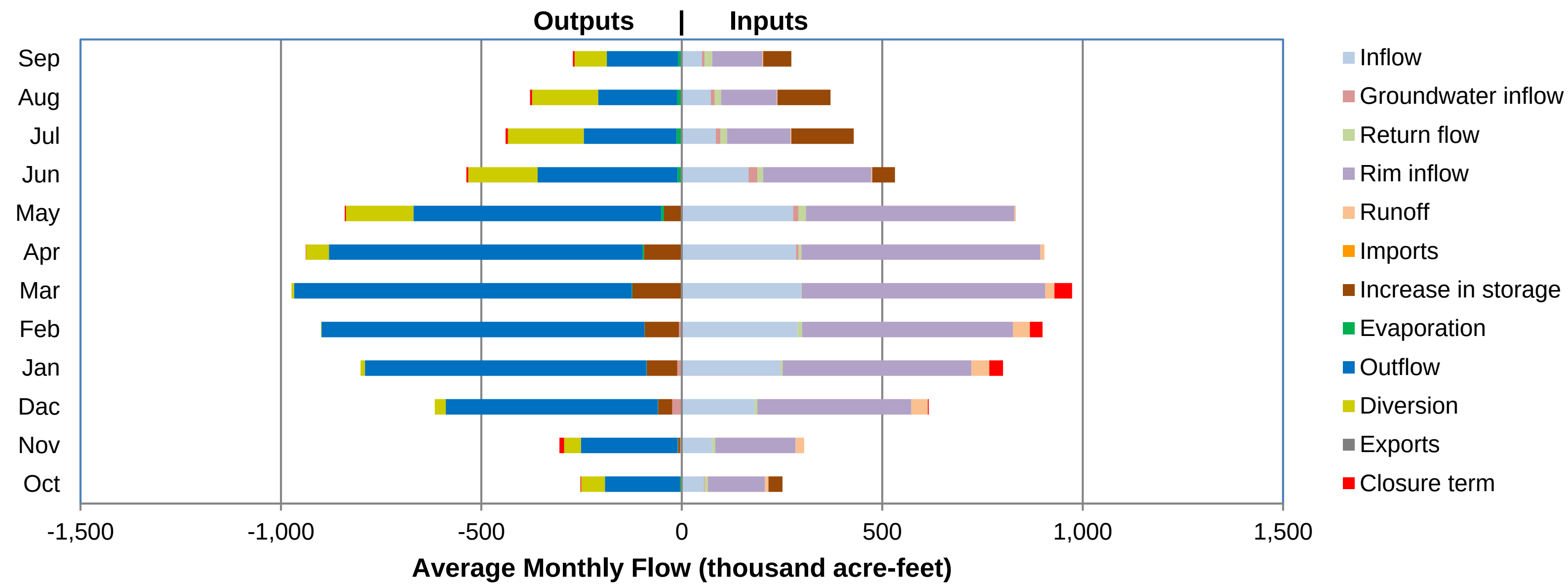
Flow Component	Average Monthly Flow (thousand acre-feet)												
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
Inflow	654	848	1,463	1,966	2,134	2,222	1,883	1,594	1,063	798	735	728	16,087
Groundwater Inflow	-6	-17	-30	-19	-12	-11	-3	-7	2	0	-1	-2	-107
Return Flow	2	3	3	2	5	1	2	6	3	3	4	7	40
Rim Inflow	0	0	0	0	0	0	0	0	0	0	0	0	0
Runoff	3	7	15	17	16	8	4	1	0	0	0	0	72
Imports	0	0	0	0	0	0	0	0	0	0	0	0	0
Increase In Storage	0	0	0	0	0	0	0	0	0	0	0	0	0
Evaporation	0	0	0	0	0	0	0	0	1	1	1	1	4
Outflow	647	841	1,468	1,981	2,165	2,247	1,888	1,579	1,043	768	706	712	16,046
Diversion	8	5	4	4	4	8	12	23	27	30	27	14	166
Exports	0	0	0	0	0	0	0	0	0	0	0	0	0
Closure Term	0	5	21	19	26	36	0	0	-1	-1	-1	-1	103

Figure 16-9. Closure Term Flow Components, Sacramento River at Freeport



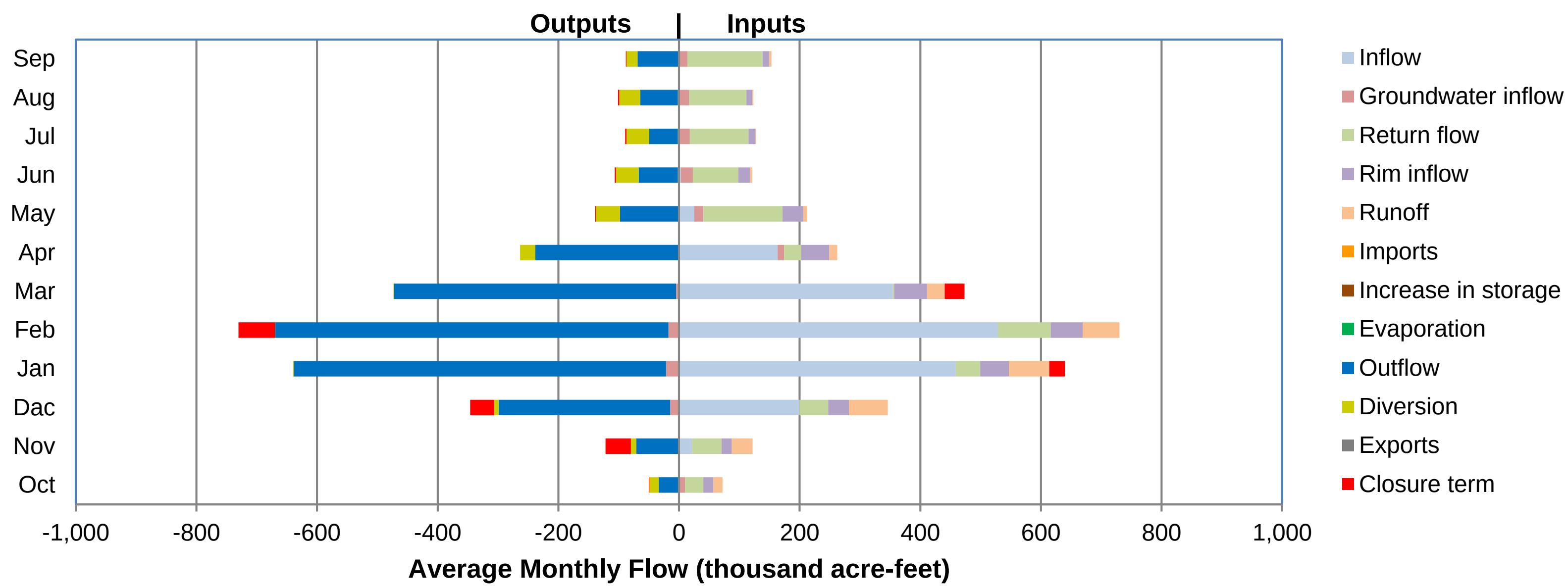
Flow Component	Average Monthly Flow (thousand acre-feet)												
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
Inflow	0	0	0	0	0	0	0	0	0	0	0	0	0
Groundwater Inflow	0	0	0	0	0	0	0	0	0	0	0	0	0
Return Flow	0	0	0	0	0	0	0	0	0	0	0	0	0
Rim Inflow	132	191	362	469	506	581	580	523	289	167	143	125	4,069
Runoff	0	0	0	0	0	0	0	0	0	0	0	0	0
Imports	0	2	3	4	5	8	8	7	3	1	0	0	40
Increase In Storage	-18	-10	-5	23	8	3	0	5	12	-3	-8	-10	-4
Evaporation	0	0	0	0	0	0	0	0	0	1	1	1	4
Outflow	135	189	360	440	493	575	575	508	261	150	130	119	3,933
Diversion	7	7	7	7	7	8	8	9	10	10	11	8	98
Exports	5	5	6	7	6	7	7	8	8	7	6	5	76
Closure Term	-3	-2	2	2	3	4	2	0	-1	-3	-3	-3	-2

Figure 16-10. Closure Term Flow Components, Feather River at Oroville



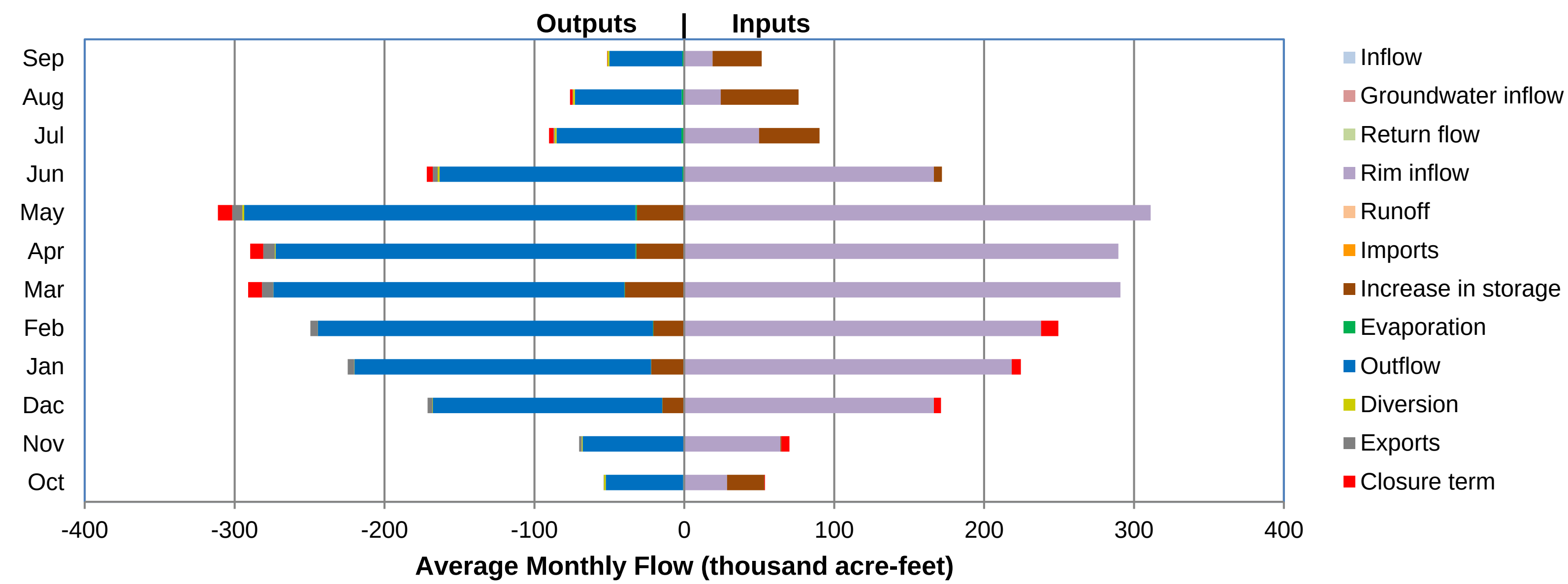
Flow Component	Average Monthly Flow (thousand acre-feet)												
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
Inflow	55	76	182	246	289	298	285	278	167	85	73	50	2,083
Groundwater Inflow	3	-4	-24	-11	-7	-2	6	13	22	12	9	7	23
Return Flow	8	7	7	5	11	1	7	19	14	16	16	19	130
Rim Inflow	142	201	384	471	526	608	596	520	270	158	139	125	4,140
Runoff	9	22	41	45	42	23	10	4	2	2	2	2	203
Imports	0	0	0	0	0	0	0	0	0	0	0	0	0
Increase In Storage	-35	5	35	76	85	122	95	44	-57	-156	-132	-70	12
Evaporation	5	1	1	1	1	2	4	7	11	13	11	9	65
Outflow	187	241	529	702	806	842	782	618	349	232	198	178	5,663
Diversion	59	42	28	11	1	7	57	168	173	189	165	81	980
Exports	0	0	0	0	0	0	0	0	0	0	0	0	0
Closure Term	-2	-12	3	34	32	44	-1	-3	-5	-6	-5	-4	75

Figure 16-11. Closure Term Flow Components, Feather River near Nicolaus



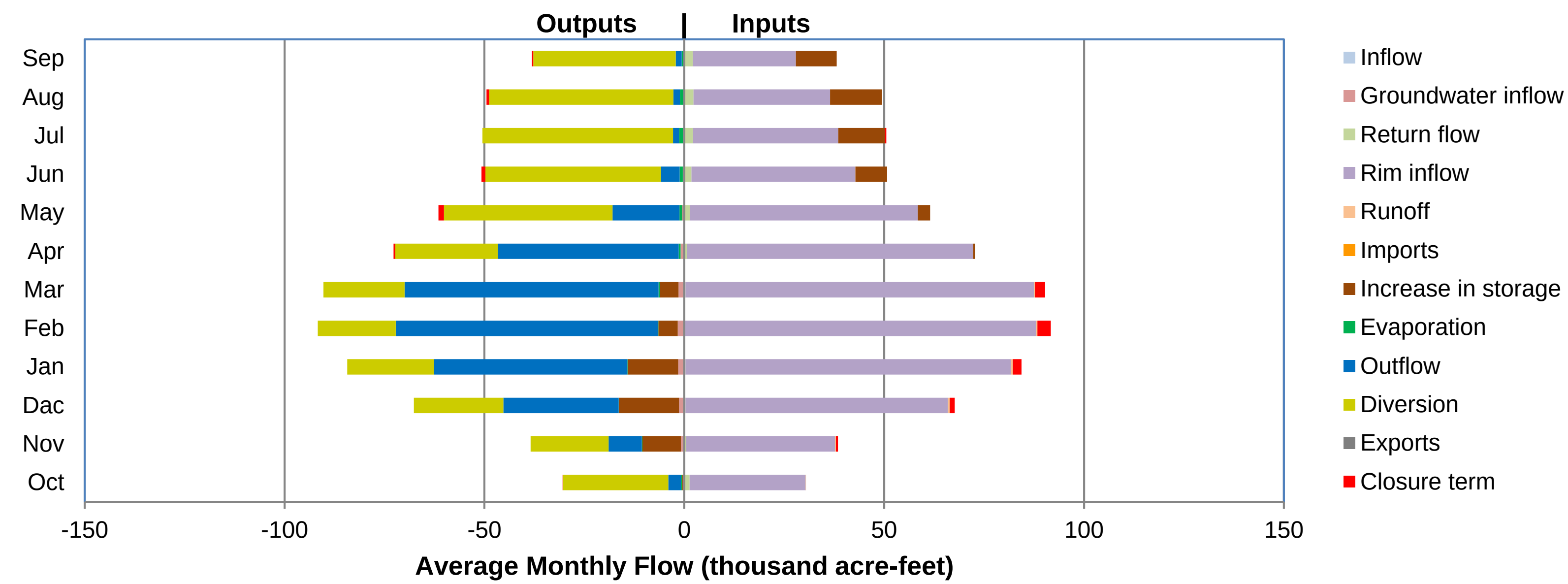
Flow Component	**Average Monthly Flow (thousand acre-feet)**												
	Oct	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Total**
Inflow	1	22	200	459	529	354	163	25	3	0	0	0	1,757
Groundwater Inflow	9	-1	-15	-21	-17	-5	11	15	20	18	17	14	43
Return Flow	30	49	48	40	87	2	29	131	75	97	95	125	808
Rim Inflow	17	17	34	47	53	55	46	34	19	12	10	11	356
Runoff	15	34	64	67	61	29	13	6	4	1	2	4	301
Imports	0	0	0	0	0	0	0	0	0	0	0	0	0
Increase In Storage	0	0	0	0	0	0	0	0	0	0	0	0	0
Evaporation	1	0	0	0	0	0	0	1	2	2	2	1	9
Outflow	33	70	284	617	652	468	238	97	65	47	62	68	2,701
Diversion	15	9	8	1	0	1	25	40	38	38	35	18	228
Exports	0	0	0	0	0	0	0	0	0	0	0	0	0
Closure Term	-1	-42	-39	26	-60	33	0	-1	-2	-2	-2	-1	-92

Figure 16-12. Closure Term Flow Components, Sacramento Slough near Karnak



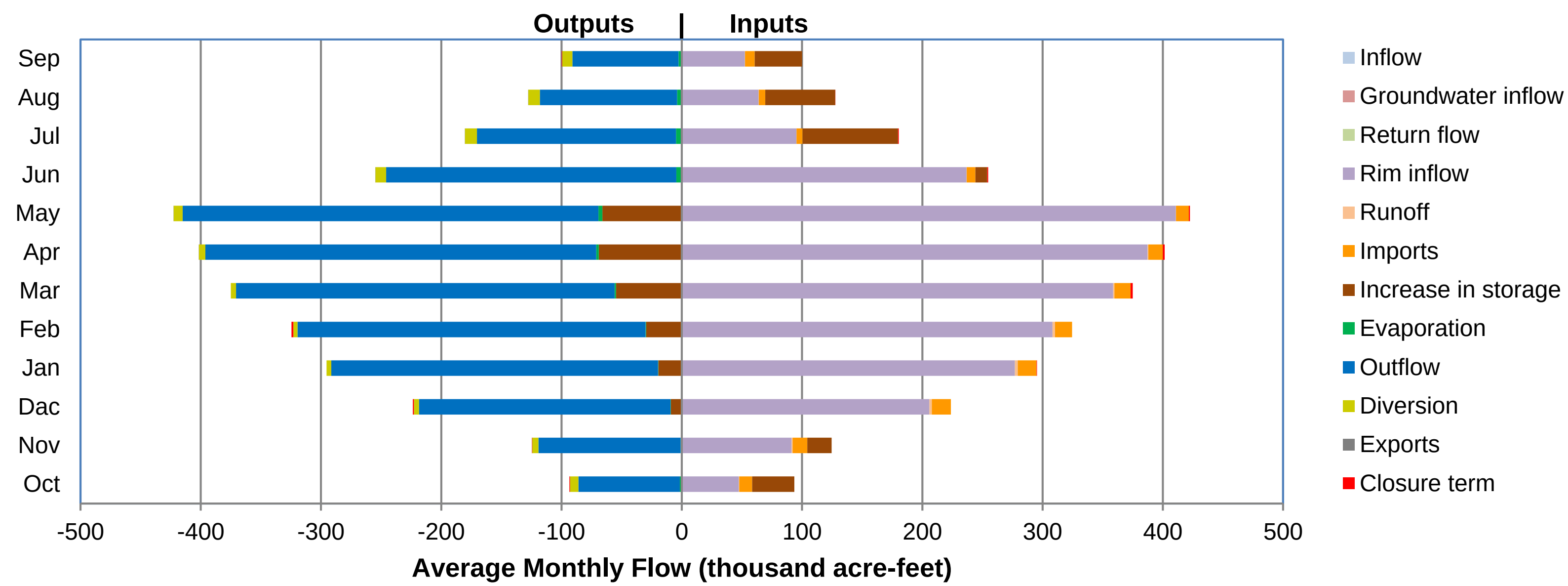
Flow Component	Average Monthly Flow (thousand acre-feet)												
	Oct	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Total**
Inflow	0	0	0	0	0	0	0	0	0	0	0	0	0
Groundwater Inflow	0	0	0	0	0	0	0	0	0	0	0	0	0
Return Flow	0	0	0	0	0	0	0	0	0	0	0	0	0
Rim Inflow	28	64	167	218	238	291	290	311	166	50	24	19	1,867
Runoff	0	0	0	0	0	0	0	0	0	0	0	0	0
Imports	0	0	0	0	0	0	0	0	0	0	0	0	0
Increase In Storage	-25	-1	15	22	21	40	32	32	-5	-40	-52	-33	5
Evaporation	1	0	0	0	0	0	1	1	1	2	2	1	10
Outflow	52	68	153	198	224	234	240	261	162	83	71	49	1,794
Diversion	1	1	0	0	0	0	1	1	1	1	1	1	10
Exports	0	2	3	4	5	8	8	7	3	1	0	0	40
Closure Term	0	5	5	6	11	-9	-9	-10	-4	-3	-2	0	-8

Figure 16-13. Closure Term Flow Components, Yuba River at Smartville



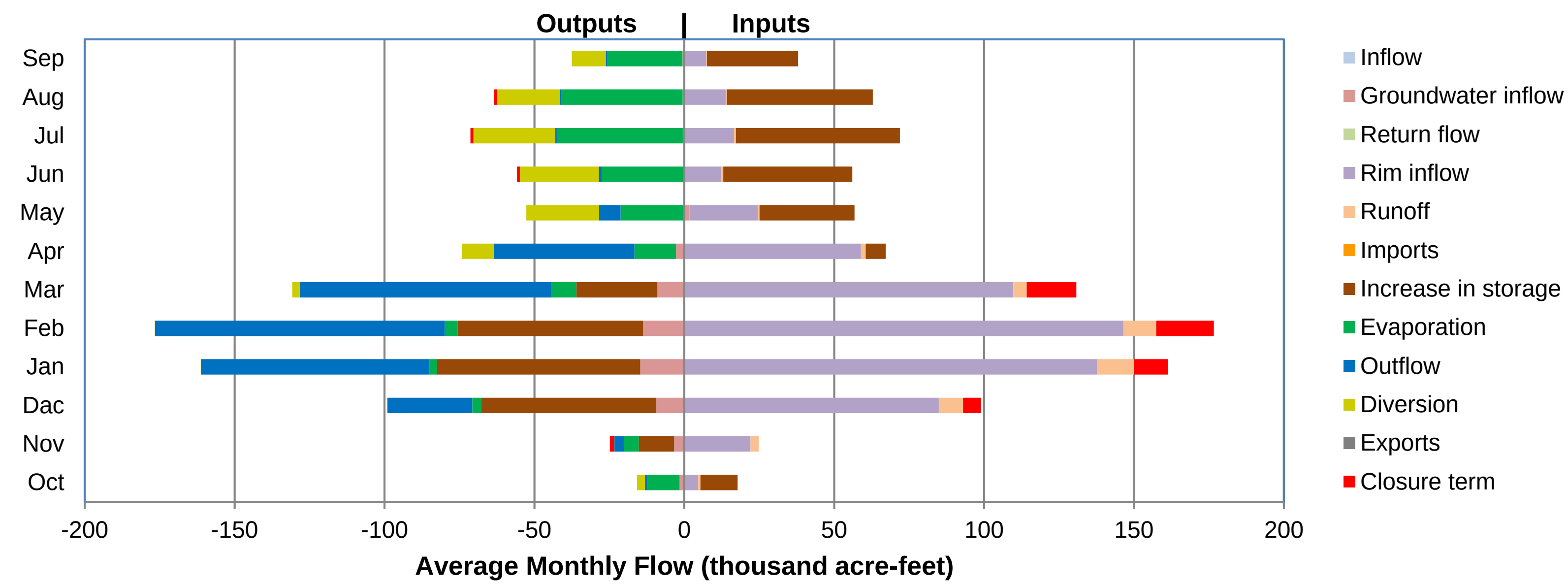
Flow Component	Average Monthly Flow (thousand acre-feet)												
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
Inflow	0	0	0	0	0	0	0	0	0	0	0	0	0
Groundwater Inflow	0	-1	-1	-2	-2	-1	-1	0	0	0	0	0	-10
Return Flow	1	0	0	0	0	0	1	1	2	2	2	2	13
Rim Inflow	29	37	66	81	88	87	72	57	41	36	34	26	654
Runoff	0	0	0	0	0	0	0	0	0	0	0	0	2
Imports	0	0	0	0	0	0	0	0	0	0	0	0	0
Increase In Storage	0	10	15	13	5	5	0	-3	-8	-12	-13	-10	1
Evaporation	0	0	0	0	0	0	0	1	1	1	1	1	5
Outflow	3	8	29	48	66	64	45	17	5	2	2	2	289
Diversion	26	20	22	22	19	20	26	42	44	48	46	36	371
Exports	0	0	0	0	0	0	0	0	0	0	0	0	0
Closure Term	0	1	1	2	3	3	0	-1	-1	0	-1	0	6

Figure 16-14. Closure Term Flow Components, Bear River near Wheatland



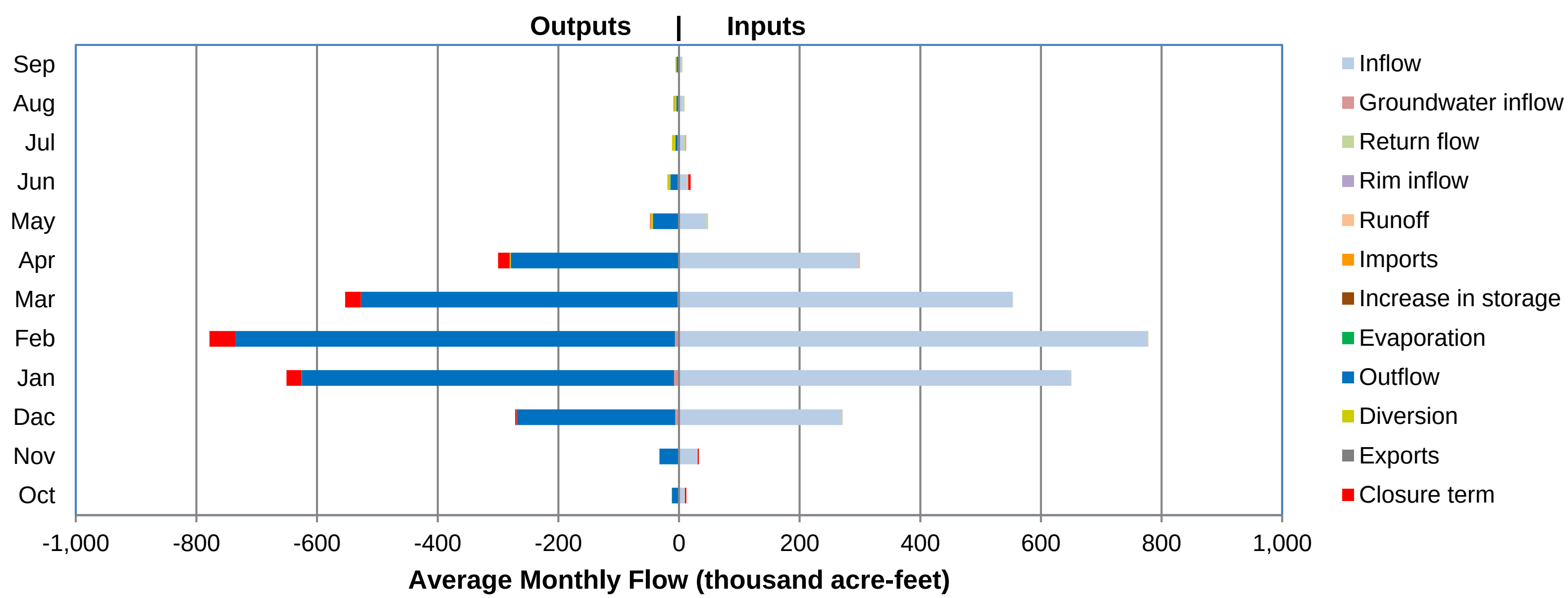
Flow Component	Average Monthly Flow (thousand acre-feet)												
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
Inflow	0	0	0	0	0	0	0	0	0	0	0	0	0
Groundwater Inflow	0	0	-1	-1	-1	-1	-1	-1	0	0	0	0	-5
Return Flow	0	0	0	0	0	0	0	0	0	0	0	0	0
Rim Inflow	47	91	206	277	308	359	387	411	237	95	64	52	2,535
Runoff	0	1	2	2	2	1	1	0	0	0	0	0	10
Imports	11	12	16	16	14	13	12	11	7	5	5	8	130
Increase In Storage	-35	-20	9	19	29	54	68	65	-10	-79	-58	-39	2
Evaporation	2	1	0	0	1	1	2	3	4	5	4	3	25
Outflow	84	118	209	272	289	315	325	346	241	166	114	88	2,568
Diversion	7	5	4	4	3	4	5	8	9	10	10	8	78
Exports	0	0	0	0	0	0	0	0	0	0	0	0	0
Closure Term	-1	0	-1	0	-1	2	2	1	1	1	0	-1	2

Figure 16-15. Closure Term Flow Components, American River at Fair Oaks



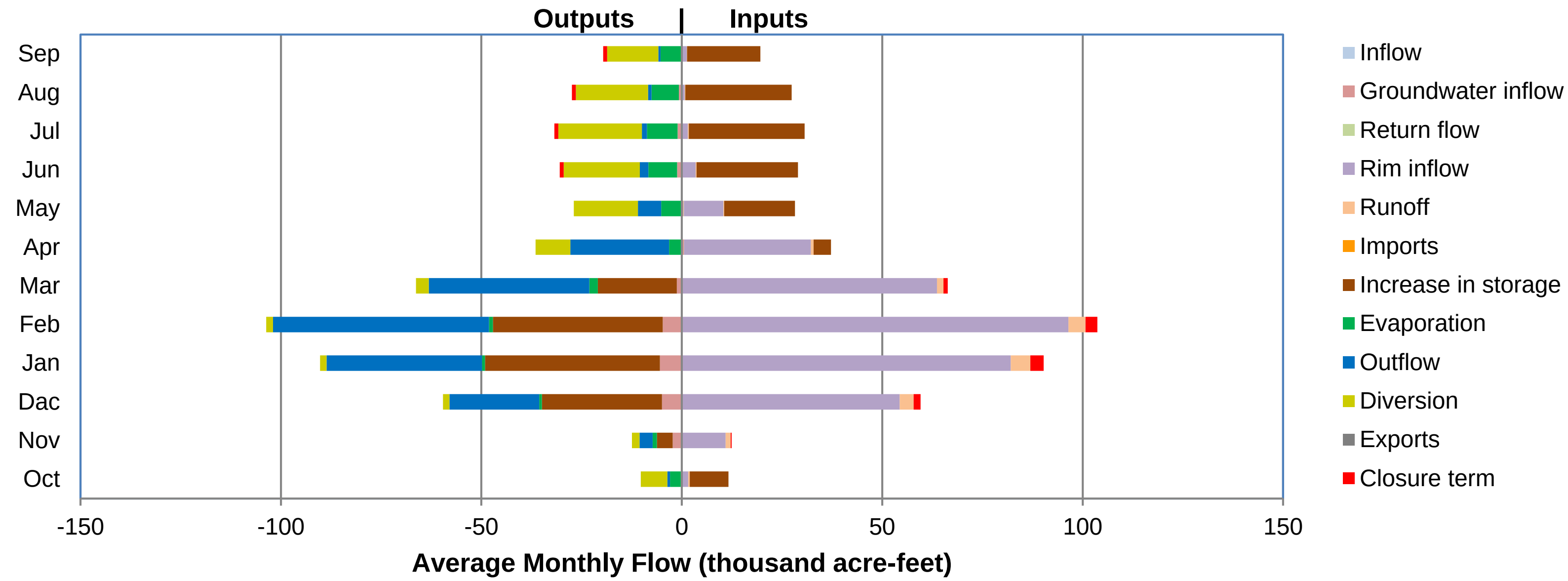
Flow Component	Average Monthly Flow (thousand acre-feet)												
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
Inflow	0	0	0	0	0	0	0	0	0	0	0	0	0
Groundwater Inflow	-2	-3	-9	-15	-14	-9	-3	2	0	-1	-1	-1	-54
Return Flow	0	0	0	0	0	0	0	0	0	0	0	0	0
Rim Inflow	5	22	85	138	147	110	59	23	12	17	14	7	637
Runoff	1	3	8	12	11	4	2	1	1	1	0	0	43
Imports	0	0	0	0	0	0	0	0	0	0	0	0	0
Increase In Storage	-12	12	58	68	62	27	-7	-32	-43	-55	-49	-30	0
Evaporation	11	5	3	2	4	8	14	21	28	42	41	25	204
Outflow	1	3	28	76	97	84	47	7	1	0	0	0	345
Diversion	3	0	0	0	0	3	11	24	26	27	21	11	126
Exports	0	0	0	0	0	0	0	0	0	0	0	0	0
Closure Term	0	-1	6	11	19	17	0	0	-1	-1	-1	0	49

Figure 16-16. Closure Term Flow Components, Cache Creek at Yolo



Flow Component	Average Monthly Flow (thousand acre-feet)												
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
Inflow	9	30	271	650	777	553	297	45	13	8	7	4	2,664
Groundwater Inflow	0	-1	-6	-8	-7	-2	1	0	-2	-1	-1	0	-27
Return Flow	1	1	1	1	1	0	1	3	3	3	2	1	16
Rim Inflow	0	0	0	0	0	0	0	0	0	0	0	0	0
Runoff	0	0	1	1	1	0	0	0	0	0	0	0	2
Imports	0	0	0	0	0	0	0	0	0	0	0	0	0
Increase In Storage	0	0	0	0	0	0	0	0	0	0	0	0	0
Evaporation	0	0	0	0	0	0	0	0	0	1	0	0	1
Outflow	12	31	263	617	729	525	279	43	12	4	4	4	2,523
Diversion	1	0	0	0	0	0	2	4	5	6	4	2	24
Exports	0	0	0	0	0	0	0	0	0	0	0	0	0
Closure Term	2	2	-2	-25	-43	-26	-19	-1	4	1	-1	0	-108

Figure 16-17. Closure Term Flow Components, Yolo Bypass near Woodland



Flow Component	Average Monthly Flow (thousand acre-feet)												
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
Inflow	0	0	0	0	0	0	0	0	0	0	0	0	0
Groundwater Inflow	0	-2	-5	-5	-5	-1	1	0	-1	-1	-1	0	-21
Return Flow	0	0	0	0	0	0	0	0	0	0	0	0	0
Rim Inflow	2	11	54	82	96	64	32	10	3	1	1	1	357
Runoff	0	1	3	5	4	2	1	0	0	0	0	0	17
Imports	0	0	0	0	0	0	0	0	0	0	0	0	0
Increase In Storage	-10	4	30	44	42	20	-4	-18	-25	-29	-26	-18	9
Evaporation	3	1	1	1	1	2	3	5	7	8	7	5	43
Outflow	1	3	22	39	54	40	25	6	2	1	1	1	194
Diversion	7	2	2	2	2	3	9	16	19	21	18	13	112
Exports	0	0	0	0	0	0	0	0	0	0	0	0	0
Closure Term	0	0	2	3	3	1	0	0	-1	-1	-1	-1	5

Figure 16-18. Closure Term Flow Components, Putah Creek near Davis

Gauge Errors

Gauge errors are apparent when values for a given closure term appear inconsistent with the magnitude of rim inflows, rainfall-runoff, or other closure terms within the Sacramento Valley. Apparent gauge errors are most evident during high-flow events. Currently, no attempt has been made to adjust the closure terms for gauge errors. However, values may be adjusted in the high-flow months in future refinements of CalSim 3.0.

Table 16-4 summarizes statistics for the 15 closure terms in the Sacramento Valley. An example of apparent gauge error is the February 1958 value of the closure term for the Sacramento River at Butte City. The value of 1,147 TAF is approximately 11 standard deviations from the mean value of the closure term.

Table 16-4. Closure Term Statistics

Description	Average Value (TAF/month)	Maximum Value		Minimum Value		Standard Deviation (TAF)
		Value (TAF)	Date	Value (TAF)	Date	
CT_BendBridge	9.1	368	Jan-56	-383	Nov-07	61
CT_ButteCity	-4.0	1,147	Feb-58	-523	Dec-05	100
CT_Colusa	-5.6	370	Jan-41	-140	Nov-70	34
CT_Davis	0.4	71	Jan-67	-97	Mar-83	6
CT_FairOaks	0.2	49	Mar-11	-56	Feb-99	6
CT_Freeport	8.6	309	Mar-83	-224	Jan-80	37
CT_Nicolaus	6.2	513	Feb-42	-659	Dec-55	65
CT_Orovl	-0.2	131	Dec-12	-124	Nov-02	9
CT_Sacslough	-7.7	905	Feb-98	-704	Feb-83	87
CT_Smartville	-0.7	182	Apr-27	-179	Mar-28	28
CT_Verona	0.6	1,588	Mar-40	-843	Jan-53	118
CT_Wheatland	0.5	48.6	Jul-15	-60	Jun-15	5
CT_WilkinsSl	-0.9	575	Jan-97	-300	Jan-41	53
CT_Woodland	-9.0	343	Jan-56	-2,211	Feb-98	104
CT_Yolo	4.1	177	Feb-98	-98	Nov-14	17
Total	1.7					

Key:
TAF = thousand acre-foot

Table 16-5 presents a summary of the closure terms for months when the closure term for the Yolo Bypass near Woodland is large and negative (representing an outflow from the system). The table shows that negative values for the Yolo Bypass closure term are often partly offset by positive values for the closure term for the Sacramento River at Verona. The major components of the closure term for the Sacramento River at Verona are gauge records for the Sacramento River below Wilkins Slough and Sacramento near Verona, Colusa Basin Drain at Knights Landing Outfall Gates, Sacramento Slough near Karnak (outflow from the Sutter Bypass), Fremont Weir, and Feather River at Nicolaus. Similarly, the major components of the closure term for the Yolo Bypass near Woodland are Knights Landing Ridge Cut (which is ungauged), Fremont Weir, and Cache Creek near Yolo. The large negative values for the Yolo Bypass closure term are believed to stem from errors in gauged flows over the Fremont Weir, difficulties in gaging flows in the Yolo Bypass, and temporary storage of water within the bypass.

Table 16-5. Examples of Apparent Gauge Errors

Location	Closure Term Values for Months when the Closure Term at Woodland (CT_Woodland) is Large and Negative (thousand acre-feet)									
	Feb-95	**Mar-06**	**Feb-00**	**Mar-98**	**Mar-00**	**Feb-58**	**Jan-06**	**Jan-98**	**Jan-97**	**Feb-98**
CT_BendBridge	149	155	117	122	201	318	182	12	25	111
CT_ButteCity	160	24	48	-15	314	1,147	194	12	-160	125
CT_Colusa	-28	48	-91	10	11	176	45	-11	-35	48
CT_Davis	-2	26	0	-3	6	18	28	0	-33	33
CT_FairOaks	-15	24	-22	-11	5	4	-4	9	3	-33
CT_Freeport	-4	20	40	241	143	-16	-24	62	-23	78
CT_Nicolaus	95	294	12	89	104	151	367	43	450	113
CT_Orovl	1	9	0	2	0	0	5	4	26	5
CT_Sacslough	232	214	-174	21	341	-606	837	-45	871	905
CT_Smartville	-30	14	-3	-71	-17	-5	-62	-10	1	-8
CT_Verona	**215**	**99**	**471**	**227**	**647**	**174**	**558**	**270**	**312**	**986**
CT_Wheatland	3	8	7	4	5	6	4	6	7	7
CT_WilkinsSl	158	437	168	270	177	46	212	263	575	303
CT_Woodland	**-524**	**-545**	**-644**	**-701**	**-719**	**-733**	**-760**	**-907**	**-979**	**-2,211**
CT_Yolo	48	54	2	40	31	142	52	34	33	177
Total	460	882	-72	225	1,250	821	1,636	-259	1,072	639